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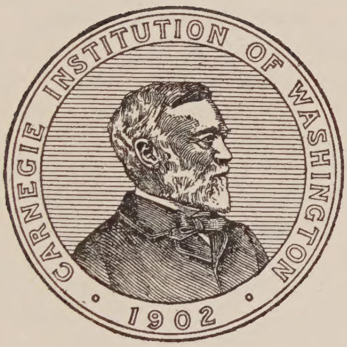
ALCOHOL AND HUMAN EFFICIENCY

EXPERIMENTS WITH MODERATE QUANTITIES AND DILUTE SOLUTIONS OF ETHYL ALCOHOL ON HUMAN SUBJECTS

By

WALTER R. MILES



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PREFACE.

This report is a presentation of experimental evidence which has been accumulating for several years on certain phases of the alcohol problem. The data offered relate to the influence of alcohol on a rather wide range of measurements, including both physiological and psychological processes. The effect on motor functions is particularly considered, first by an extensive study in which typewriting by skilled operators was used, and later by experiments in which certain new techniques for measuring motor coordination ability were introduced.

A special feature of this report, and one that is relatively new in alcohol literature, is the study of very dilute beverages with an effort to relate data on the absorption of alcohol to objective measures of the pharmacodynamic effects.

The discussion has not been overburdened by much comparison with results published by other workers. The fact is that little has been done with solutions as dilute as those used in the majority of our experiments, and the present need is for self-consistent and extensive data rather than for extensive generalizations. The report suffers from a good deal of repetition in the description and portrayal of results for different sets of experiments since they are on the same topic and have many measurements in common. The restatement of experimental conditions and the frequent use of certain phrases, for which unfortunately there seem no good substitutes, are in the interest of definiteness and to avoid ambiguity.

Throughout the experimentation the work has benefited very much from the kindly interest and the wise criticism of Dr. F. G. Benedict, Director of the Nutrition Laboratory. Dr. T. M. Carpenter also generously assisted me not only in the experiments reported in Chapter IV, as noted there, but likewise by his careful criticism of the routine for alcohol analysis of urine samples, by the checking of stock solutions used for dosage purposes, and by frequent discussions of methods and alcohol data.

The author is greatly indebted to the men who so faithfully served as subjects in the various experiments; to Dr. J. C. Aub for help in finding medical-school students to serve as subjects; to Dr. H. F. Root for taking blood samples; to Mr. E. S. Mills, who skillfully cooperated as laboratory technician in taking measurements in all the various series, and who, with several other present and past members of the Laboratory staff, had a large part in working up the data; to Mr. E. L. Fox for the preparation of the charts; and finally to Miss A. N. Darling, whose invaluable editorial work has been done under the special handicap of the author's change of academic position before the manuscript was entirely ready for the printer.

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CHAPTER I.

GENERAL CONSIDERATIONS AND TECHNIQUE.

INTRODUCTION.

The action of ethyl alcohol on the human organism is a topic of enduring interest. Various phases of the problem have been under investigation at the Nutrition Laboratory for several years past and a number of publications have been issued.[A] It is therefore unnecessary to restate or to emphasize the scientific importance of the topic as a nutritional problem, and as a question of psycho-dynamics. Practical considerations, strongly accentuated in recent years by the severe military and economic stress generally present throughout the world, have brought the alcohol problem into prominent view and undoubtedly have prompted a more thorough investigation.[B]

The toxic effects of alcohol are chiefly observable in the motor incapacity of the drinker. No very refined scientific methods are necessary to observe the differences existing between the normal state and that of profound or average intoxication. Medical physiology and psychology early demonstrated that the effects of large and often-repeated doses were clearly harmful to the organism. The point of controversy has been and will continue to be the question of the effect of "moderate amounts."

[A] Note A.—The various publications of the Nutrition Laboratory which relate to phases of the alcohol problem are as follows:

- Benedict and Dodge. Tentative plan for a proposed investigation into the physiological action of ethyl alcohol in man: Proposed correlative study of the psychological effects of alcohol on man. Privately printed, Boston, 1913.
- Dodge and Benedict. Psychological effects of alcohol. An experimental investigation of the effects of moderate doses of ethyl alcohol on a related group of neuro-muscular processes in man. Carnegie Inst. Wash. Pub. No. 232, 1915.
- Higgins, Peabody, and Fitz. A study of acidosis in three normal subjects with incidental observations on the action of alcohol as an antiketogenic agent. Journ. Med. Research, 1916, **34**, p. 263.
- Benedict. The alcohol program of the Nutrition Laboratory, with special reference to psychological effects of moderate doses of alcohol on man. Science, 1916, **43**, p. 907.
- Higgins. The rapidity with which alcohol and some sugars may serve as nutriment. Am. Journ. Physiol., 1916, **41**, p. 258.
- Carpenter. Physiological effects of ethyl alcohol when injected into the rectum, with special reference to the gaseous exchange. Am. Journ. Physiol., 1917, **42**, p. 605. (Abstract.)
- Higgins. Effect of alcohol on the respiration and the gaseous metabolism in man. Journ. Pharm. and Exp. Therapeutics, 1917, **9**, p. 441.
- Carpenter and Babcock. Absorption of alcohol and its concentration in the urine when injected by rectum. Journ. Biol. Chem., 1917, **29**, p. xxviii. (Abstract.)
- Miles. Effect of alcohol on psycho-physiological functions. Carnegie Inst. Wash. Pub. No. 266, 1918.
- Carpenter and Babcock. The concentration of alcohol in the tissues of hens after inhalation. Am. Journ. Physiol., 1919, **49**, p. 128. (Abstract.)
- Miles. The comparative concentrations of alcohol in human blood and urine at intervals after ingestion. Journ. Pharm. and Exp. Therapeutics, 1922, **20**, p. 265.

[B] Note B.—Recently, important work of this character has been in progress in England. Lord D'Abernon (Alcohol: Its action on the human organism, New York, 1918) and a prominent committee of scientific men have made a digest of the alcohol literature and summarized the present state of scientific knowledge regarding the effects of moderate amounts of ethyl alcohol taken as single doses.

Their statement of the practical problems which appear to them to need further investigation is suggestive. Concomitant with this summing up of the present status of the question, Mellanby (Med. Research Com., Sp. Rept., Ser. No. 31, London, 1919; also British Journ. Inebriety, 1920, **17**, p. 157), Vernon (Med. Research Com., Sp. Rept., Ser. No. 34, London, 1919, and British Journ. Inebriety, 1920, **18**, p. 39), and McDougall and Smith (Med. Research Council, Sp. Rept., Ser. No. 56, London, 1920) have pursued investigations in which they emphasize the necessity of strictly defining the alcohol dosage in any such experiments. A summary of scientific alcohol results has also been published by Thunberg (Alkoholens Fysiologiska Verkningar, Stockholm, 1920). A number of papers have likewise been written by Widmark (Tirfing, Stockholm, 1920, Nos. 5 and 6, p. 1), and one by Hammarsten and Liljestrand (Supp. A to Gov't Pub., Stockholm, 1922, **37**, p. 119), which have to do especially with the absorption and utilization of alcohol, and, like the work of Mellanby, should not be neglected by future investigators who attempt a study of the physiological and psychological effects of alcohol dosages. Meyer, in a recent periodical review of the psychological effect of drugs (Psychol. Bull., 1922, **19**, p. 175) devotes most of his attention to alcohol and states some of the problems which appear to him as still unsettled. Of the recent alcohol bibliographies, the one of most importance is that of the Index Catalogue of the Library of the Surgeon General's Office, Washington, 1918, Ser. III, vol. 1. This supplements the standard bibliographies on the subject, i. e., those of Abderhalden (Bibliographie der gesamten wissenschaftlichen Literatur ueber den Alkohol und den Alkoholismus. Berlin and Vienna, 1904) and Viazemsky (A bibliography on the question of alcoholism. Moscow, 1909, 1st ed.). The chemico-physiological literature is especially well represented in the bibliographies given in papers by Schweisheimer (Der Alkoholgehalt des Blutes unter verschiedenen Bedingungen. Diss., Leipsic, 1913), and recently by Haneborg (The effects of alcohol upon digestion in the stomach, Acta Medica Scand., supp. I, 1921), while Miles has cited 80 or more titles in a recent paper (The comparative concentrations of alcohol appearing in human blood and urine, Journ. Pharm. and Exp. Therapeutics, 1922, **20**, p. 265).

The experiences of everyday life are usually so intricate that they do not offer a satisfactory opportunity to observe carefully the behavior of others or to judge accurately the efficiency of one's own reactions and performances in relation to the influence of so subtle a factor as moderate amounts of alcohol introduced into the organism. The problem is one which must be taken into physiological and psychological laboratories. A laboratory study does not necessarily epitomize the whole of life, nor state the question from every angle, but it is a method which may be relied upon to reveal facts of certain types, and thus to clear up difficulties in the way of a complete understanding of the whole problem. This book is a report of such laboratory studies. It is this pure and simple. There is no attempted generalization upon the alcohol question at large. There is not even a consecutive review of the literature relating to previous experimentation with small amounts and dilute doses of alcohol. These compilations have been made by others and will doubtless be made again. Our contribution is confined to first-hand objective experimental evidence given in such detail that the reader may draw his own conclusions rather than be forced to accept those of the author.

The need of rigidly scientific investigations, with results stated in objective form, free from personal bias of the investigator, can hardly be too much stressed in this case. It may seem that of the many factors that may modify the general working efficiency of the human organism, the ingestion of ethyl alcohol is one of those most open to direct investigation. But the problem is many-sided and in a peculiar sense requires concomitant lines of research, for while the question may seem clear and apparently easy of solution, it remains a fact that the results which have been reported are often at variance with each other. Suggestions have been made elsewhere[a] to account for the difficulty in harmonizing published results, which at times seems an impossibility.

REQUIREMENTS FOR DETERMINING THE EFFECT OF ALCOHOL.

There are four considerations which seem to us of prime importance in the conduct of alcohol research: (1) exactness in the matter of alcohol dosage, (2) provision for suitable control experiments, (3) the liberal discarding of first or practice results with all untrained subjects, and (4) the provision of strictly objective measurement techniques.

In the first place, the real intensity of the alcohol dose should be known, i. e., the factor of dilution must not be neglected. By dilution is meant the mixture of the alcohol with other fluids in preparing the experimental beverage, and likewise the mixture of this diluted alcohol[b] with any food and fluids which may be in the stomach. If food is taken with the alcohol or was taken shortly before the ingestion, it is perfectly obvious that a different condition of dosage exists from that when the alcohol is taken into an empty stomach. In theory this has always been admitted, but very vaguely considered in the experimental literature. Until the recent British work by Vernon[c] and McDougall and Smith,[d] there has been only a minimum of direct experimentation on this problem in which human subjects were used and their physiological or psychological reactions measured when the alcohol has been taken with and without food. A great deal has been written about the influence of various alcoholic beverages and the difference in their constituents, other than ethyl alcohol, has been stressed. However, pharmacologists seem to agree that it is primarily the ethyl alcohol in these beverages which produces the results upon the nervous system. From the work of Mellanby,[e] it appears probable that the other substances in common beverages as well as the presence of food exert their chief influence by modifying the rate of absorption of alcohol through the walls of the stomach. The real intensity of the alcohol dose employed in any instance is thus not indicated by simply stating the number of cubic centimeters of absolute alcohol ingested, for aside from the minor and quite temporary influence upon the mucous membrane of the mouth[f] and the lining of the stomach, it is the alcohol that passes from the stomach into the circulation and body tissues that acts as the effective agent in producing any change in the functional activity of the organism.

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[a] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 7.

[b] It is not common to take the alcohol wholly undiluted, but an instance of this is the research of Lange and Specht (Zeitschr. f. Pathopsychol., 1915, **3**, p. 155), who permitted some of their subjects to take 40 c. c. of absolute alcohol in a 99 per cent solution. See their page 203.

[c] Vernon, Med. Research Com., Sp. Rept., Ser. No. 34, London, 1919.

[d] McDougall and Smith, Med. Research Council, Sp. Rept., Ser. No. 56, London, 1920.

[e] Mellanby, British Med. Research Com., Sp. Rept., Ser. No. 31, 1919, p. 20.

[f] Féré, Compt. rend. Soc. biol., 1900, **52**, p. 825.

The real intensity of alcohol dosage employed in any series of experiments may be kept satisfactorily constant by using always the same alcohol dilution in the experimental beverage and by having uniform conditions in reference to the ingestion of food. Accurate statements should be made regarding dosage and conditions. There is also a possibility growing out of recent chemical-physiological work of determining the amount of alcohol present in the body fluids by taking samples of blood or urine at various intervals following the ingestion and analyzing these samples for their alcohol content. In most of the experiments reported in this volume, particularly those made from 1919 onward which involve very dilute solutions, we have tried to carry out both of these procedures, i. e., (*a*) to keep the dosage and food conditions constant, and (*b*) to determine the amount of alcohol present in the body fluids on the basis of that appearing in the urine. Full discussion of the results will be given in the following chapters.

The second general consideration is the provision of adequate control experiments. Alcohol when introduced into the system can not be suddenly withdrawn as one might discontinue electrical stimulation or the subjection of the individual to the influence of some sort of radiation. The factor has been absorbed into the organism and the course of its influence must in general be allowed to complete itself. It is known from many studies on the absorption, utilization, and final disposition of alcohol that after a single dose it seldom disappears from the body in less than 6 to 8 hours; consequently it is not feasible to have an extended normal experiment and an alcohol experiment on the same day. One or more preliminary periods of measurement should precede the taking of the alcohol dose on any particular day. These preliminary data serve as normal for the day, and are contrasted with the performance after alcohol but do not form by themselves an adequate base-line for estimating the effect of alcohol. It may easily happen that the performance after the preliminary period of measurement normally becomes improved or, on the other hand, may be poorer. It is necessary to make blank or control experiments, in which the preliminary periods, the dosage (aside from alcohol), the duration, and the general conditions are the same as those obtaining in the alcohol sessions.

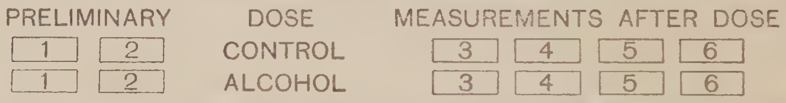

Fig. 1.—Diagram Illustrating the Arrangement of Periods of Measurement in Comparable Control and Alcohol Experiments for Isolating the Alcohol Effect.

The rigid isolation of the effect of alcohol when both control and alcohol experiments have been made may be discussed with the aid of a diagram, figure 1. The two experiments are represented in two horizontal lines of blocks. Each block is a period of measurement and, for simplicity, will be considered as one test. Preceding the control dose the test is given twice, blocks 1 and 2. Following the control dose, it is repeated at intervals represented by blocks 3, 4, 5, and 6. Similarly, periods of testing preceded and succeeded the alcohol dose. Actually in figure 1 the alcohol data are confined to periods 3, 4, 5, and 6 following the alcohol dose. The question to be determined is whether the data for these periods differ from normal data.

There are really three sets of normal data, the preliminary periods before alcohol, the preliminary periods before the control dose, and the performance after the control dose was ingested. These represent different angles for viewing and judging the strictly alcohol performance. A statement of the effect of alcohol should take the whole picture into account.

The computation is simple and is as follows: Periods 1 and 2 of the control experiment are averaged. This average is compared with the individual values for periods 3 to 6 after the control dose by deducting the average from the value obtained in each of these periods. In the same manner, periods 1 and 2 before alcohol are averaged, and the average is deducted from each period following the alcohol. The result is two sets of comparisons or differences between preliminary and after dosage performances. One set of differences, i. e., those from the control experiments, is normal or basal. These are therefore deducted algebraically from the alcohol differences. The result represents in units of the particular measurement the change produced by the alcohol factor. For computing this change in terms of percentage, the general average of periods 1 and 2 (control) and of 1 and 2 (alcohol) is used as a basis.

Working ability is unavoidably different from day to day, so that each subject should ideally serve more than one control day and more than one alcohol day after having become somewhat habituated to the experimental routine. The third requirement, and one, we feel, which is of great importance if the true alcohol effect is to be carefully isolated, is the avoidance of too great economy in the number of experiments performed. Our alcohol experiments each require the greater part of a day, and as they take the time of a subject, experimenter, and an assistant, they are expensive, but, at least with human subjects, it is necessary to make them in considerable number. At the beginning of the series with any untrained subject, many other factors due to the novelty of the laboratory conditions are as likely to produce measurable changes as is the alcohol. It is absolutely essential that the subject be given some initial practice. This must be liberal and should include at least the first control and the first alcohol experiments. These should be carried out, however, with the regular routine and in every way as if the data were to be used or in fact were to be the only data available. But after the completion of the experiments the results, if calculated, should be discarded unless of course the process of learning is itself the measurement under consideration. If, then, the results of the first days are discarded and the subject is subsequently measured on each of two or more control and alcohol days, trustworthy evidence may be expected. It is futile to think that he will not improve in the tests throughout the series of experiments. For this reason it is advisable that of those experiments which are to be finally considered for estimating the alcohol effect, one or more controls should come at the first and also a control experiment at the end of the series.

The fourth consideration, which has been much stressed at the Nutrition Laboratory in connection with alcohol researches, is that of providing thoroughly objective measurement techniques covering a wide range of neuromuscular processes. This point was strongly emphasized throughout the publication of Dodge and Benedict, is frequently referred to in the present report, and is too obvious to need extended discussion. The description of techniques to follow in this chapter, as well as the presentation of experimental results in later chapters, will testify to the importance which the author attaches to this matter of strictly objective evidence on the alcohol problem.

In planning the researches reported here, constant attention has been given these four important features, which appeal to us as the main requirements for determining the influence of alcohol on psychological and physiological processes with human subjects.

OUTLINE OF STUDIES.

All the alcohol experiments reported in this monograph were made in the psychological laboratory of the Nutrition Laboratory in Boston. In 1914 the author repeated a series of experiments on a medical student used in the alcohol research of Dodge and Benedict[a] and in his publication of the results[b] supplemented the earlier report in various ways. Typewriting was later chosen as an important and regular occupational task which could be profitably studied in connection with alcohol. Typewriting lends itself better than most skilled work to a clear-cut separation of speed and accuracy, and the factor of difficulty is under control. Sets of typewriting tasks were carefully prepared, and these, with other neuro-muscular tests, were used on a group of trained typists. The work was done in 1914–15. It was expected at that time to report the typewriting results independently and to continue research in the alcohol field, taking up the problem of dilution and working especially with very weak solutions. Many interruptions, notably the extensive low-diet research conducted at the Nutrition Laboratory,[c] delayed the execution of this plan. Work with dilute beverages was not begun until 1919, and then was discontinued for a year because of absence of the investigator for several months in Europe. The different series of experiments are therefore not closely consecutive, nor are they always closely related to each other. But the series are similar in that all are studies of the physiological and psychological effects of ethyl alcohol, much the same techniques have been employed, and the same capable laboratory technician, Mr. Edward S. Mills, has helped with the measurements throughout. The final alcohol results for each series have been computed recently, i. e., each series has been made more or less independently without quantitative knowledge of the alcohol effect in the experiments which may have preceded it. A change of academic position necessitates the discontinuance of the author's work on alcohol problems at the Nutrition Laboratory, and it seems advisable to publish these studies together in chronological order. The series have been numbered for convenience and are briefly described. The data are given in the same chronological order in succeeding chapters, and the way these data substantiate each other and make clear the general picture for the alcohol effect will appear there.

I. *Influence of alcohol on efficiency in typewriting and on the performance of simpler related acts.*—Five young men, all trained typists, acted as subjects. Each man served on six different days. The first was control, the second alcohol, and the results of these two experiments were discarded. The third and sixth days were control days, the fourth with 30 c. c. of alcohol (dose A), and the fifth day with 45 c. c. of alcohol (dose B). The alcohol was taken without food and on an empty stomach. The details are given in table 1, page 33. The experiments were continued for 4 hours after the alcohol was taken. Typewriting tests of varying difficulty were used, and in the discussion of the results special attention is given to the accuracy and legibility of the typewriting after the ingestion of the alcohol. A variety of psychological measurements were made in the intervals between the periods of typewriting. For discussion of the results of this series, see Chapter II, pages 29 to 95.

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 55. See footnote.

[b] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918.

[c] Benedict, Miles, Roth, and Smith, Carnegie Inst. Wash. Pub. No. 280, 1919.

II. *Repetition series of typewriting experiments.*—These were divided into two parts:

(*A*) Two series of experiments were made on one typist to find if the subject would demonstrate substantially the same effect of alcohol in a duplicate series. The dosage and food conditions were the same in both, but in one case the experiment continued 3 hours and in the other 5 hours. For discussion of the data obtained, see Chapter III, pages 96 to 102.

(*B*) Two series of experiments were made on each of two subjects, the dosage and general conditions being the same, except that in the second series the alcohol was taken very shortly after a full meal eaten at the Laboratory. This arrangement was specifically to measure the influence of food on the effective intensity of the alcohol ingested. The results are discussed in Chapter III, pages 102 to 110.

III. *Effect of dilute alcohol given by rectal injection during sleep.*—One man, a medical student, was given a series of psychological tests for an hour and a half in the evening. During the night, while he was in a respiration chamber, a 500 c. c. solution, containing 37.5 grams of alcohol (7.5 per cent by weight) diluted with water to the required amount, was given by rectal injection while the subject was asleep. In the morning, about 6 hours after the injection and before the taking of food, the subject was again carefully tested in the psychological laboratory. Three control and three alcohol experiments were made. The evening results are contrasted directly with those obtained in the morning. The metabolism of the subject was measured during the night, and standard electrocardiograms were frequently taken to ascertain the effect which the alcohol might have on the heart during sleep. For discussion of the results of series III, see Chapter IV, pages 111 to 124.

IV. *Effect of very dilute alcohol (2.75 per cent by weight) on a trained subject.*—This large group of experiments may also be divided into two parts:

(*A*) Five series of experiments were made, in each of which there were several control and alcohol days. The amount of alcohol ingested was always the same (27.5 grams) and was taken with the same degree of dilution (2.75 per cent by weight). Various beverages were used as dilutants, these being water, beer substitute, grape juice, and cider. A wide variety of neuro-muscular tests were employed, in all of which the subject had had much previous practice. Urine samples were regularly collected at half-hour intervals and analyzed for alcohol content, so that the relative amount of alcohol in the body fluids might be correlated with the intensity of the alcohol effect. A standard amount of food was always taken a certain length of time (2 hours) prior to the ingestion of the 1-liter dose. The control days duplicated the content and volume of the alcohol dose in each series, except for the omission of the alcohol. The periods in each experiment were 30 minutes in length and 6 in number; 1 and 2 were preliminary, 3, 4, 5, and 6 followed the dose. The data obtained are discussed in Chapter V, pages 125 to 180.

(*B*) In 11 series of experiments with the same trained subject, a standard dose was used of 27.5 grams of alcohol diluted with grape juice and water to a total volume of 1 liter. These tests included experiments (1) with standard conditions as shown in (*A*); (2) with subject in post-absorptive condition taking the standard dose; (3) with prolongation of period of ingestion; (4) with standard dose and an additional one-half liter taken in small portions; (5) with standard dose and an additional 900 c. c. taken in small doses; (6) with a double standard dose but the same conditions as in (*A*); (7) with one-half liter of water taken 1 hour before the alcohol; (8) with one-half liter of whole milk taken 1 hour before the alcohol; (9) with one-half liter of water taken 1 hour after the alcohol; (10) with one-half liter of whole milk taken 1 hour after the alcohol; (11) with periods of moderate muscular work, alternated with periods of psychological measurements. In all cases 15-minute periods were used and urine samples were obtained with like frequency. There were 2 preliminary periods and 14 periods following the dosage; the total 16 periods with the interval for ingestion thus required about 4½ hours. The alcohol in the urine was determined and the concentration curves thus obtained are compared with the data showing the effect of alcohol on the various measurements. The results of the experiments in these 11 series are discussed in Chapter V, pages 180 to 203.

V. *Effect of very dilute alcohol (2.75 per cent by weight) on a group of young men.*—These experiments were conducted primarily to determine if the results that had been obtained with the trained subject could be considered as typical of the effect of alcohol under these conditions of dosage and dilution. The young men, principally medical students and used to moderate amounts of alcohol, served in two preliminary experiments. In the first, 27.5 grams of alcohol were diluted with grape juice and water to a total volume of 1 liter, and in the second the same weight of alcohol was diluted to 100 c. c. with grape juice and water. Venous-blood samples and closely following urine samples were taken at various intervals during these two experiments. The subjects were given intensive practice in the different psychological measurements, but all of the psychological results in the preliminary days were disregarded when the effect of alcohol was computed. On four succeeding days with each subject, six 30-minute periods, two preliminary and four following dosage, were used and only urine samples were taken with the regular neuro-muscular measurements. The standard dose of 27.5 grams of alcohol diluted with grape juice and water to 1 liter was ingested on two of these days (the fourth and fifth). On the other days the same quantity of grape juice and water served as a control dose. The alcohol content of the urine samples was determined in order to compare the intensity of the alcohol effect with these data on the effective intensity of the alcohol dosage. The comparison of the alcohol concentration in the blood samples and in the urine samples obtained on the preliminary days makes possible statements of the availability of such urine samples for use in alcohol experimentation. For discussion of the results of series V, see Chapter VI, pages 204 to 260.

From this outline it will appear that we have endeavored to take careful account of the effectiveness of the alcohol dosage selected for experimentation. In our early work this has been done by defining and controlling the conditions surrounding the dosage. In the later series we have added to our data the very important comparison results showing directly the alcohol content of the body fluids at the time when the effect of the alcohol on the nervous system was measured. We have included in this study a liberal number of control experiments, so that, except in the series with the trained subject in which 15-minute periods were used (see p. 180), there are as many control as alcohol experiments. And finally, with all untrained subjects the results for the first two days of experimentation have been completely discarded, although the tests were carried out with conscientious care and completeness. This group of studies contributes most distinctly to the question of the influence of alcohol taken in very weak solution.

MEASUREMENTS AND TECHNIQUES.

Previous alcohol experimentation at the Nutrition Laboratory has brought out the fact, which is of course observable in some other investigations, as well as in everyday life, that the effect of alcohol is characteristically shown in motor functions. In planning the researches to be reported in the following chapters, we have continued to use several of the measurements which served in the investigation conducted by Dodge and Benedict, but, in view of the results which they obtained, it seemed desirable that the range of measurement should be supplemented more especially as to motor coordinations. Our study has therefore become chiefly one upon the effect of alcohol on motor control, with special attention given to the use of measurements which make possible the collection of data as to the influence upon the adequacy and accuracy as well as speed of motor coordination.

The variety of objective tests or indicators which have served in our various experimental series may be listed as follows, with additional statement as to the individual studies in which the different measurements were made. The Roman numerals used for designating the various studies are the same as those employed in the previous section. A description of each technique is subsequently given.

Physiological Measurements.

Pulse-rate	III, IV A, V.
Heart-rate (string galvanometer)	I, II A and B.
Tetanus heart-rate	III.
Standard electrocardiograms	III.
Skin temperature	V.
Metabolism (oxygen consumption)	III, IV A.
Urine and blood (alcohol content)	IV A and B, V.
Diuresis (total volume of urine)	IV A and V.
Patellar reflex	V.
Protective lid reflex	I, II A and B, III.

Psychological Measurements.

Reactions:	
Eye reactions	III, IV A.
Word reactions	I, II A and B.
Sensory thresholds:	
Electric shock	III, IV A.
Visual acuity	III, IV A.
Motor coordinations:	
Typewriting (tasks of varying complexity)	I, II A and B.
Eye movements	I, II A and B, III, IV A and B.
Finger movements	I, II A and B, III, IV A and B, V.
Discrete eye-hand coordinations (pursuit pendulum)	IV A, V.
Continuous eye-hand coordination (pursuitmeter)	IV A and B, V.
Static equilibrium	IV A and B, V.
Mental test:	
Johnson code (substitution test)	IV A and B, V.

Physiological Measurements.

Measurement of Heart Action.

Three methods have been used for recording the pulse or heart-rate: (1) counting radial pulse at the wrist; (2) counting from a stethoscope placed over the apex of the heart; (3) recording photographically by the use of the string galvanometer, with body-leads worn below the axilla. The first two methods need no special description. The counts for (1) came after the subject had been sitting well relaxed in a steamer chair for several minutes, and were timed by a stop-watch. The routine consisted of a count of 20 pulse-beats and a series of three or more counts. The average of these three counts was considered as the pulse-rate for that period. The counts were all made by the same individual, who used two or three stop-watches, so that the time readings could be checked by an assistant. The results are given in beats per minute and are discussed on pages 178 and 225.

When the heart-rate is measured by the electrical method with a string galvanometer, no attention is given to the character of the record, but only the duration of the heart cycle is considered, and it is most convenient to measure from R to R. Condensers are used when taking such records, so that no compensation is required for change in skin current. Such records of the heart-rate have the advantage that they can be taken when the subject is active, and this method was accordingly found useful in the typewriting experiments. The body electrodes were small and flexible and never irritated the skin or gave discomfort. They were put on at the beginning of the session and worn constantly for the 4 or 5 hours of the experiment. The fact that the typewriter on which the subject's fingers were playing was wired with a direct current of 110 volts gave some difficulty for a time. Even during the experiments there were a good many records when the galvanometer string showed some agitation as a result of the fingers touching keys which were charged, but for the most part the records were quite uniformly legible, so that the pulse-cycles could be measured with accuracy.

The "tetanus pulse" was also measured by the string galvanometer with the subject of the rectal feeding experiments, the records being taken continuously when the man was at first sitting quietly, then vigorously active (supporting his whole weight in chinning a bar) and in the recuperative period of 30 seconds following this activity. A discussion of this type of measurement, with illustrative records, is given in previous publications.[a] The conditions and special technique for the standard electrocardiograms which were used with the subject of the all-night experiments with the rectal feeding of alcohol are given in Chapter IV, page 119.

SKIN TEMPERATURE.

The change in the temperature of the skin following the ingestion of alcohol is commonly spoken of as an effect of the drug. While there has been much dispute as to the effect of alcohol on the pulse-rate and the blood-pressure, the vascular dilation effect on the peripheral blood-vessels has been admitted without question.[b] With those habitually used to taking large amounts of alcohol or large volumes of alcoholic beverages, this dilation becomes chronic, with a resultant flushing, particularly of the face.

The effect of alcohol upon the peripheral blood-supply as indicated by subjective appearances of warmth and changes in the color of the skin merits direct experimental study with an adequate technique for measuring skin temperature. As the Nutrition Laboratory had a very simple technique for such measurements, previously developed by Dr. Benedict and used by him extensively in experiments as yet unpublished, the opportunity was taken of adding this measurement to our study of dilute beverages. The technique has been described.[c] The essential scheme of the apparatus is a copper-constantan junction, one end of which is kept in a constant-temperature bath—a Dewar flask filled with liquid at approximately 34° C. The other end, in the form of a hairpin, may be applied to the skin. A sensitive galvanometer is in series with the thermo-couple. The deflections were each day standardized by placing the hairpin portion of the thermo-couple in a second flask with a given temperature difference of approximately 5° between the two flasks. As applied for the measurement of the skin temperature, the hairpin junction is mounted in a rubber handle and one side is protected by cotton. The junction is applied to any portion of the skin for approximately 6 to 8 seconds before the galvanometer reading is made. This is sufficient time for it to reach the temperature level of the skin and too short a time for much building up of temperature from below. The results are entirely satisfactory for comparative purposes.

Measurements of the skin temperature were used only in the last study, that with the group of young men taking doses of very dilute alcohol. The results are discussed on page 231.

MEASUREMENT OF METABOLISM.

A minor amount of data was collected regarding the metabolism after alcohol ingestion. The subject of the all-night experiments with rectal feeding of alcohol was measured by Dr. Carpenter in the clinical respiration chamber.[d] Only the results for the oxygen consumption are published. (See p. 121.)

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[a] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 92. Benedict, Miles, Roth, and Smith, Carnegie Inst. Wash. Pub. No. 280, 1919, pp. 151 and 415.

[b] D'Abernon, Alcohol: Its action on the human organism. New York, 1918, p. 78.

[c] Benedict, Miles, Roth, and Smith, Carnegie Inst. Wash. Pub. No. 280, 1919, p. 78; also Benedict, Miles, and Johnson, Proc. Nat. Acad. Sci., 1919, 5, p. 218.

[d] Benedict and Tompkins, Boston Med. and Surg. Journ., 1916, 174, pp. 857, 898, 939.

In experiments on the trained subject with alcohol much diluted with various substances, the metabolism was measured approximately 3 hours after the ingestion of the drug. The first form of the Benedict portable respiration apparatus was used for determining the oxygen consumption in successive periods while the subject was reclining in a steamer chair. The technique for this apparatus has been fully described in a previous publication of the Carnegie Institution.[a] The results of the metabolism measurements are discussed on page 177.

URINE AND BLOOD SAMPLES.

In the studies with very dilute alcohol made with the trained subject and with the group of young men, urine samples were regularly collected at the end of the last preliminary period and following each period after the control and alcohol doses were ingested. The volume of these samples was always carefully noted, so that comparison could be made of the diuresis following alcohol with that following the ingestion of the control solution. Samples that followed the alcohol dose, as well as some of those that were collected after the control dose, were analyzed to determine the alcohol content. The analyses were made by the Widmark-Nicloux method as modified and used in the Nutrition Laboratory.[b] These data on the alcohol content of the urine are compared with the intensity of the alcohol effect shown by the various measures. In the series with the young men using doses of very dilute alcohol, samples of venous blood were also taken in preliminary experiments to ascertain the actual relationship between the alcohol appearing in the urine as compared with that in the blood. Full discussion of this problem and of the evidence of the utility of the urine-alcohol results in such physiological and psychological experiments is given in the consideration of the data. (See pp. 211 and 261.)

PATELLAR REFLEX.

The method of measuring the patellar reflex was somewhat more simple than that previously used and described,[c] although the same general technique was employed. While the subject reclined in a steamer chair, a light lever system was attached over the quadriceps muscle of the left leg, with the foot resting on the floor and the knee flexed at approximately a right angle. After the apparatus had been adjusted to a suitable height,[d] and the intensity of blow most satisfactory for stimulating the reflex of that particular subject had been determined, conditions were kept as nearly constant as possible throughout the series of experiments. The pendulum hammer was released by hand at intervals of 5 seconds, and 25 to 30 reflexes were recorded. This measurement was used in but one study (that with the group of young men taking dilute alcohol) and only the reflex amplitude was measured. The results are discussed on pages 235 to 238.

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[a] Benedict, Boston Med. and Surg. Journ., 1918, 178, p. 667; also, Benedict, Miles, Roth, and Smith, Carnegie Inst. Wash. Pub. No. 280, 1919, p. 82.

[b] Miles, Journ. Pharm. and Exp. Therapeutics, 1922, 20, p. 265. The essentials of this modified method are also explained in Chapter VI, p. 210.

[c] Benedict, Miles, Roth, and Smith, Carnegie Inst. Wash. Pub. No. 280, 1919, p. 155. This technique is the same as that used by Dodge and Benedict (Carnegie Inst. Wash. Pub. No. 232, 1915, p. 36), with some modifications.

[d] Benedict, Miles, Roth, and Smith, loc. cit., p. 160, fig. 33.

PROTECTIVE LID REFLEX.

The regular stimulus in the measurement of the protective lid reflex was a sound caused by the snapping of a spring against a sounding board placed near the subject. The recording was by Dodge's well-known photographic method, by which the shadow of the eyelash is made to record on a horizontally moving plate.[a] A small strip of black paper, 1 by 16 mm., was attached to the left lid to intensify the shadow cast by the eyelash. This paper commonly remained in place continuously throughout the session, unless accidentally brushed off. The recording photographic light was interrupted by a tuning-fork arrangement, so that the time ordinates appeared directly on the photographic record.[b]

Voluntary winking tends to complicate these records of the protective lid reflex. It has been shown that this voluntary winking modifies the latency of the reflex and influences the amplitude of the reflex.[c] In accordance with the method employed in previous researches with this measurement at the Nutrition Laboratory, two sound stimuli were used, the object being to obtain data on the reflex when taken during the relatively refractory period. The experimenter can, by close attention, release the camera and stimulus apparatus at a moment when the subject appears to be free from voluntary winking. Thus the first reflex will be uncomplicated by the winking. The second reflex is, however, so frequently disturbed by this factor that the results for the primary reflex only are used in the discussion. The latency of the reflex was measured in 0.001 second from the photographic record which contains time ordinates in 0.01 second. The heights are given in millimeters and represent a magnification due to the artificial eyelash.

The lid reflex was used in three of the researches, the two typewriting studies and the study with the rectal injection of alcohol. The discussion of the results obtained are given on pages 77 and 116.

PSYCHOLOGICAL MEASUREMENTS.

EYE REACTIONS.

The measurement of the eye reactions was made in but two studies, that in which the rectal injection of alcohol was used and the study with the trained subject. In the former, the technique was similar to that described by Dodge and Benedict,[d] these reactions in turning the eye to a new point of regard being registered photographically. All measurements were made with the right eye. The technique was modified by mounting the stimulus mark in an eccentric position on a disk which was rotated to six different axial positions. The stimulus mark was thus always the same distance from the fixation mark. The dropping of the shield which exposed a new stimulus position also allowed a recording beam of light to fall upon the eye.

The technique with the trained subject was the same as that used in a low-diet research previously made by the Nutrition Laboratory.[e] In this research the Dodge technique was further modified, so that the subject looked at a light fixation mark in the center of a dark field. The stimulus was applied by the sudden illumination of another point in this field, which might be on any one of several axes or at various distances from the central fixation mark. The natural tendency would be to look at the point thus illuminated. The photographic beam of light fell on the eye of the subject at the same moment that the new light appeared and the time counted from the photographic plate was from the beginning of the illumination until the moment the eye of the subject began to turn toward it. The time unit of the record was 0.01 second; the results are given in 0.001 second. The discussion of the data obtained for the measurement of the eye reaction may be found on pages 117 and 162.

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 58; Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 28.

[b] See illustrative records, Dodge and Benedict, loc. cit., p. 60; Miles, loc. cit., p. 55.

[c] Miles, loc. cit., p. 56.

[d] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 78.

[e] Benedict, Miles, Roth, and Smith, Carnegie Inst. Wash. Pub. No. 280, 1919, p. 159.

Word Reactions.

The subject was required to read common 4-letter English words as quickly as possible after each was exposed separately. He spoke the words into a voice-key tube, and the accuracy of the reaction was constantly checked by the experimenter. The technique was the same as that described by Dodge and Benedict[a] and by Miles.[b] The same series of words was used over and over, but rearranged each time, so that the subject had no possible way of anticipating the order of exposure. Both exposure and reaction were indicated by the same Deprez marker, recording on a rapidly moving kymograph drum. Sharp, distinct pronunciation was insisted upon; the results obtained are believed to be very consistent and trustworthy. This measurement was used only in the two typewriting studies. The data obtained are discussed on page 87.

Sensory Threshold for Electric Shock.

The technique used for taking the electric threshold was the same as that previously employed in the low-diet research carried out by the Nutrition Laboratory and has been fully described in an earlier publication.[c] By employing a direct current and a continuously acting Lucas pendulum constructed at the Nutrition Laboratory, shocks of approximately threshold intensity were given to the finger-tips of the subject. A resistance of 200,000 ohms was in series with the fingers. The introduction of this high resistance rendered fluctuations in skin resistance of no consequence. The duration of the shock, about 0.0035 second, was kept the same in all tests, but the voltage was altered, and the threshold value was found in terms of voltage. Usually the first and second fingers of the right hand were tested, these being immersed in salt solution to a depth of 2 cm.; the electrodes were of the non-polarizable type. Any slight abrasion of the skin caused the electric shock to be felt sharply as pain rather than as a dull throb or muscle-twitch which is the characteristic sensation. The shocks were given periodically about 2.5 seconds apart, and occasionally blanks were introduced. The subject responded by pressing a key when he felt the shock. The measurement of the electric threshold was used in the study with rectal injection of alcohol, and also with the trained subject. A discussion of the results is given on pages 116 and 165.

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 90.
[b] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 62.
[c] Benedict, Miles, Roth, and Smith, Carnegie Inst. Wash. Pub. No. 280, 1919, p. 176.

VISUAL ACUITY.

The measurement of visual acuity was made with the same two subjects as that of the sensory electric threshold. With the trained subject it was used in but one series, the electric threshold being substituted in the subsequent tests. The visual acuity was measured by means of an Ives-Cobb visual acuity object, which was placed at the end of a dark hood, 170 cm. from the eye of the subject, and viewed through an artificial pupil 3 mm. in width. The method of use is fully described in a previous publication.[a] Briefly, a series of alternating dark and light bands can be made so small as to be indistinguishable, or so large that one or two bands occupy the whole field. In the test, the bands are gradually increased in width until the subject recognizes the presence of bands and can state the axes at which they point. But one eye is tested, in this case always the right eye. The results of this test of visual acuity are discussed on pages 116 and 165.

TYPEWRITING.

A standard commercial typewriter was provided with electrical circuits, so that distinct records of the movement of the printing-keys, the space-bar, and the carriage shift were produced on a kymograph rotating at a fairly rapid speed. Time records were incorporated in this graphic tracing of the typewriting performance; the various features of the record could thus be accurately measured. Full details of this technique are given in connection with the discussion of the results of the two typewriting series of experiments. (See pp. 38 to 42 and figs. 8 and 9.)

EYE MOVEMENTS.

The speed of eye movement was measured in all of the five studies except that with the group of young men using very dilute alcohol. The technique in the two series of typewriting experiments and in the study in which the alcohol was given by rectal injection was the same as that used by Dodge and Benedict[b] and by Miles,[c] and is full described by them. According to this method, the velocity of horizontal eye movements between two fixation points[d] separated by 40 degrees on the subject's arc of vision was recorded photographically by a soft beam of blue light reflected from the right eye, while the left eye was covered. The durations of the adductive and abductive movements were measured separately, the time unit of measurement being 0.01 second and the results are given in 0.001 second. Accuracy in moving the eye the full distance between the points was emphasized in the instructions to the subject. Discussions of the results obtained in these studies with this measurement may be found on pages 83 and 117.

In the tests with the trained subject, a later modification of the technique was used, which has been described with illustrative records in reporting the low-diet investigation[e] made by the Nutrition Laboratory. According to this modified routine, a metronome was set at 100 beats per minute, the subject shifting the point of regard with each stroke of the metronome.

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[a] Benedict, Miles, Roth, and Smith, Carnegie Inst. Wash. Pub. No. 280, 1919, p. 169.

[b] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 77.

[c] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 28.

[d] In the technical literature this kind of eye movement is known as the "saccadic" type. See Dodge, Psychol. Bull., 1916, 13, p. 422.

[e] Benedict, Miles, Roth, and Smith, Carnegie Inst. Wash. Pub. No. 280, 1919, p. 184.

The time unit in the record was 0.004 second, with the results given in 0.001 second. Two records were made on one plate in each period. As the corrective movements were very small with the trained subject, they were neglected in recording the results, since there appeared to be no difference between the control and alcohol measurements in this respect. The eye-movement data obtained with the modified technique in this study with the trained man are discussed in Chapter V, pages 149 and 183 et seq.

FINGER MOVEMENTS.

The measurement of the finger movements was the only neuro-muscular test used in all of the five studies included in this report. It was the easiest and most quickly performed measurement. The technique varied, however. In the earlier observations (the two typewriting studies, and the study by rectal injection) the method was the same as that employed by Dodge and Benedict.[a] The subject rested his forearm on a stand of suitable height and lightly grasped a vertical post to give his hand and arm a comfortable position, which was relatively free from swaying movement. A very light lever system was attached by means of a small rubber band to the middle finger and communicated the motion to a thin vertical arm which cast its shadow across the slit of a continuous-paper photographic camera. The movements were thus recorded photographically, and the heart-rate was usually taken simultaneously with the string galvanometer. There were no artificial stops for the finger movements, and the subjects were encouraged to use the amplitude of oscillation which best suited them, and made possible their maximum speed. The test continued for not more than 8 seconds.

In the later studies, a modified technique was used in which tracings on a kymograph were substituted for the photographic records. A time record was directly incorporated with the finger-movement tracing. The procedure has been fully described in the report of the low-diet research, in which it was used.[b] The oscillations were continued at maximum speed for about 12 seconds. The kymograph moved at the rate of 50 mm. per second, and the oscillations could be readily counted. The discussion of the measurements of the speed of finger movement obtained in the various studies is given on pages 81, 117, 141, 183 et seq., and 243.

There now follow the techniques for four measurements which have never been described in any publication of the Carnegie Institution, and they are therefore given with considerably more detail. Three of these—the pursuit pendulum, the pursuitmeter, and the station test—have been developed since the publication of the psychological techniques given in the low-diet research report. They were devised as a result of tests of prospective aviators and were especially planned for use in alcohol research.

DISCRETE EYE-HAND COORDINATION WITH PURSUIT PENDULUM.

In the typical psychological reaction experiment, the subject endeavors to produce a certain motor change following as quickly as possible a certain stimulus change. The essential feature of the motor response is its initiation rather than its amplitude and the factor that is measured is the interval which elapses from the stimulus change until the beginning of the motor change. An example of this is the reaction of the eye turning in the direction of a stimulus (some flash or movement) which occurs in the peripheral visual field. This is a natural reaction in the everyday behavior of the organism. Under laboratory conditions we are interested in measuring the duration from the moment of stimulus change until the moment when the eye begins to turn in the direction of the stimulus. It is obvious in this case that the eye must not only turn in the direction of the stimulus, but continue to move until the object which acted as a stimulus is seen in clear vision. If the object itself moves, then the eye performs what is called a pursuit movement, endeavoring to match the eye movement exactly to the progress of the stimulus.

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 168; Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, pp. 26 and 84.

[b] Benedict, Miles, Roth, and Smith, Carnegie Inst. Wash. Pub. No. 280, 1919, p. 186.

A pursuit movement, therefore, is at the beginning composed of a reaction, followed by a series of what we may term anticipatory reactions. If the stimulus object is moving at varying rates of speed as would be executed by a pendulum, the reaction changes of the eye will be more frequent than with a steady rate of speed. Like the typical reaction movement, the pursuit movement as a complex of simpler motor patterns, could be represented by the time value which separates it from the other object pursued, but there is also the added consideration of whether the pursuit lags behind or at times is in advance of the moving object. The simple reaction of the laboratory is an arbitrary situation which is taken out of its natural setting as it occurs in common behavior. Such a reaction is usually only the beginning of a coordinating movement towards some end or of a series of such coordinations, and the adequacy with which the series of coordinations or extended reactions is carried through is fully as important as the mere matter of quickness in initiating them. There are many situations in everyday life where one must react to moving rather than essentially stationary objects. These moving objects set a pace or pattern for the reaction of the subject, and this calls for a particular speed and amplitude of adjustment.

As a simple means for providing a test of the adequacy of single pursuit movements, we have developed the pursuit pendulum.[a] Its present noncomplicated form was to facilitate its use outside the laboratory. The essential scheme includes a pendulum, carrying a reservoir filled with water which is allowed to flow out from the lower extremity as the pendulum swings. The individual under observation attempts to catch the water in a cup of limited diameter, using a separate cup for each double swing.

The schematic arrangement is shown in figure 2. From a stout bracket which extends about 45 cm. from the wall, a pendulum, *b*, 140 cm. long, made of galvanized iron pipe, 13 mm. inside diameter, is suspended by two hooks. The shaft of the pendulum passes through the reservoir, which is firmly secured to it and made leak-tight. Openings are made in the pipe-shaft on a level with the floor of the reservoir and air-vents placed above in the shaft. The water in the reservoir thus flows freely and at the lower end is reduced by the small nozzle, *h*, to a stream 3 mm. in diameter. As the reservoir is placed about midway the length of the pendulum, the head of water changes but slightly with the decreasing level in the can. A 4-kg.

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[a] Miles, Psychol. Rev., 1920, 27, p. 361.

weight provides a fairly constant center of mass for the pendulum and allows for certain adjustments of its period, which in this case was set at 2 seconds for a complete double swing. A simple arrangement is provided for retaining and releasing the pendulum. This is clamped at one end of a sink, over which the pendulum is supported. The nozzle *h* rests on a cushion of rubber tubing, *j*, which prevents any water from escaping when the pendulum is at rest. The nozzle is held in place by a catch *k*. The small rubber-headed hammer *l*, with hinge at *m*, is held nearly upright by the operator until a signal is given by the subject. The pendulum starts its swing 0.3 second after this hammer is released. By this method the subject, without psychological training, feels that he is in control, and that the pendulum is not being released at an inconvenient time for him.

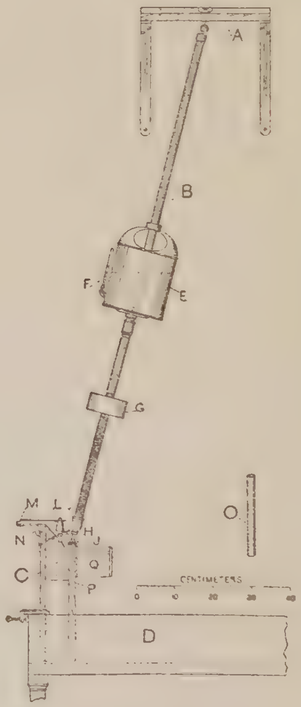

FIG. 2.—Diagram of Pursuit Pendulum.

A, wall bracket; *B*, pendulum carrying reservoir *E;* gauge *F* determines volume of liquid in reservoir; *G*, adjustable weight, regulating period of swing of pendulum; *C*, wooden frame clamped to sink *D;* nozzle *H* of pendulum held by catch *K* against rubber tubing *J* until released by fall of hammer *L*, hinged at *M;* short section of chain *N* determines lift of hammer; *O*, cup of limited diameter, in which the expelled liquid is to be collected by the subject under test; *P*, position at which cup *O* is held at start; *Q*, short-stop for ending the catch.

The cups in which the liquid is caught are made of thin-walled brass tubing, with an inside diameter of 19 mm. and a length of about 22 cm. A cup is held at position *p* against the wooden frame and about 2 cm. below the nozzle *h*. No water leaks into the cup previous to the release, and with quick reaction it is possible to begin the hand movement almost in register with the pendulum. A short-stop, *q*, limits the return movement of the cup and allows a distance of 2 cm. in which the operator may catch the pendulum and return it to its starting position for the next trial with the second cup.

Under standard conditions the pendulum delivers 50 c. c. of water per double swing, i. e., a catch of 50 c. c. is possible to the subject. The water-level in the reservoir is commonly adjusted after 10 catches, thus keeping the period of the pendulum and the delivery of the water to within 1 per cent for successive swings. If the subject collects nearly all the liquid expelled, the opening in the cup should be reduced.

In the tests reported here, the tip of the pendulum moved a horizontal distance to the right of 70 cm. The subject sat on a stool in front of the sink with his shoulder nearly opposite the point of support of the pendulum. The initial movement was made from left to right. There was a certain amount of swaying of the trunk as well as movement of the arm during the pursuit. The test consisted of 25 trials and could easily be made in 5 minutes. The catch of each cup was measured individually by a float-scale arrangement, which was inserted into the cup, and finally the bank of 25 cups was emptied into an inclined tray which drained into a large graduate. On this graduate the total catch of the 25 cups could be read. This catch was the sum of the individual readings and is the score which we used in recording the data.

The pursuit pendulum was used in the two studies with very dilute alcohol, i. e., with a trained subject and a group of young men. The results are discussed on pages 155 and 248.

Continuous Eye-Hand Coordination With Pursuitmeter.

In the test with the pursuit pendulum, the reactor made a number of separate trials, each complete in itself, and thus corresponding to a series of the usual reaction tests. The results therefore represent a series of spurts, or effort peaks. It is well known that under the influence of alcohol or some such similar factor, men often exhibit an ability to pull themselves together for a quick or intense motor response and can produce a result which varies but slightly from the normal performance.[a] A continuous task, providing few or no opportunities for much relaxation, ought therefore to show the more characteristic effect of the factor under consideration. Such a continuous test of the pursuit nature has been devised at the Nutrition Laboratory and termed a "pursuitmeter." The full description of this apparatus, with a comparison of it with similar arrangements known to the author, has been published elsewhere.[b]

The task required of the subject in this case is that of compensating changes in an electrical circuit which are automatically induced by a disturbing device beyond the control of the subject. Regular commercial electrical instruments were adapted to the purpose by certain changes, principally in the windings of the field coils. The general scheme of the pursuitmeter is shown in the wiring diagram, figure 3. *A* is a wattmeter of horizontal edgewise type and zero center scale. This is viewed by the subject and is the only part of the apparatus with which he has anything to do. It may be termed the stimulator. *B* and *C* of figure 3 are two test meters for integrating the errors of compensation, *B* accumulating those errors which are allowed to occur on the left-hand side of the zero position of *A*, *C* accumulating the errors on the right-hand side of the zero position. *D* is a curve-drawing wattmeter with zero center scale which draws with reduced amplitude the fluctuations of the needle of *A*. The field coils in all four of these instruments are wound differentially, so that each field has four field binding-posts. When equal currents of opposed direction pass through the two field windings of an instrument, the two electrical fields thus established neutralize each other so that no movement occurs in the armature of the instrument.

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 246.

[b] Miles, Journ. Exper. Psychol., 1921, 4, p. 77.

The amperage in one circuit is disturbed by a combination of harmonic motions in the induction apparatus *E*, thus setting the task for the subject of compensating these changes by the slide-wire regulator *F*, in the other circuit. The disturber mechanism is operated by a motor *G*, with a worm-gear reduction for driving the counter-shaft. *H* and *I* are a voltmeter and an ammeter, respectively, for standardizing the current in the disturbed circuit. These adjustments are made by rheostats *J* and *K*, the former controlling the speed of the rotary converter *L*, which at the Nutrition Laboratory was necessary to provide alternating current.

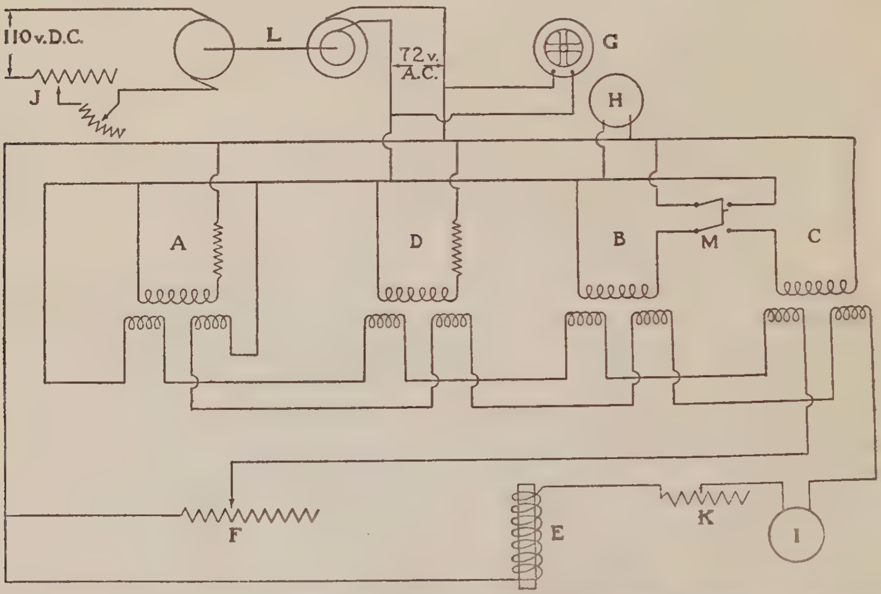

Fig. 3.—General Wiring Diagram for Combination of Electrical Instruments Which Make Up the Pursuitmeter.

For explanation of lettering on figure, see text.

For convenience in manipulating the subject and his surroundings, the stimulus wattmeter *A* and the rheostat regulator *F* are mounted in one unit (see fig. 4), which may be located a considerable distance from the other portion of the apparatus. To provide satisfactory visual conditions, a screen *M*, 23 by 34 cm. and faced with gray oatmeal paper, was attached to the front of the wattmeter; the scale of the wattmeter behind the curved glass was faced with the same material. This has proved to be a comfortable background upon which to observe movements of the diamond-shaped needle, which is white, as in the figure. The white line which extends across

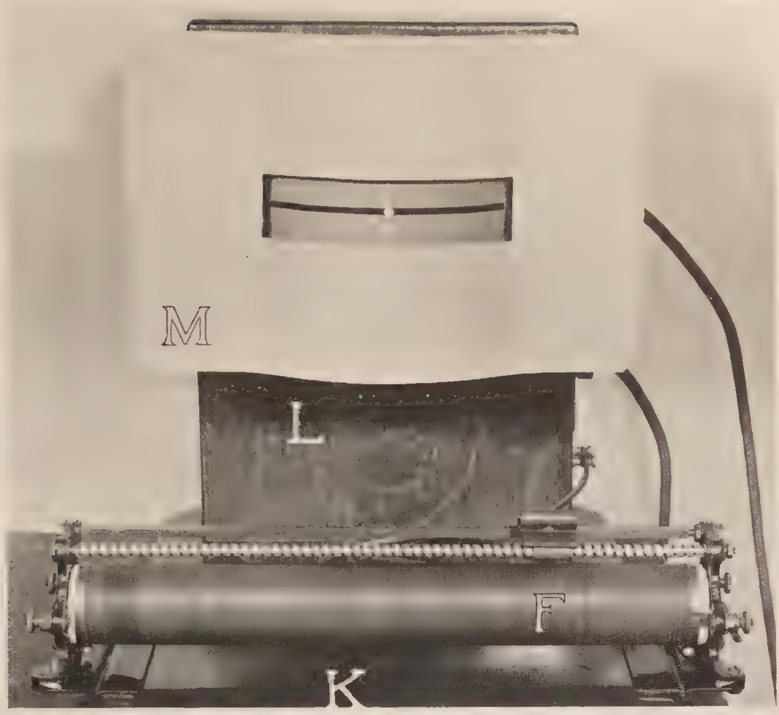

FIG. 4.—Front View of Stimulus Wattmeter and Regulator Rheostat.

Stimulus wattmeter is attached to cabinet *L*, fastened to platform *K*; *M*, screen; *F*, slide rheostat. By the manipulation of the rheostat a subject endeavors constantly to keep the wattmeter needle on the white zero line, as illustrated.

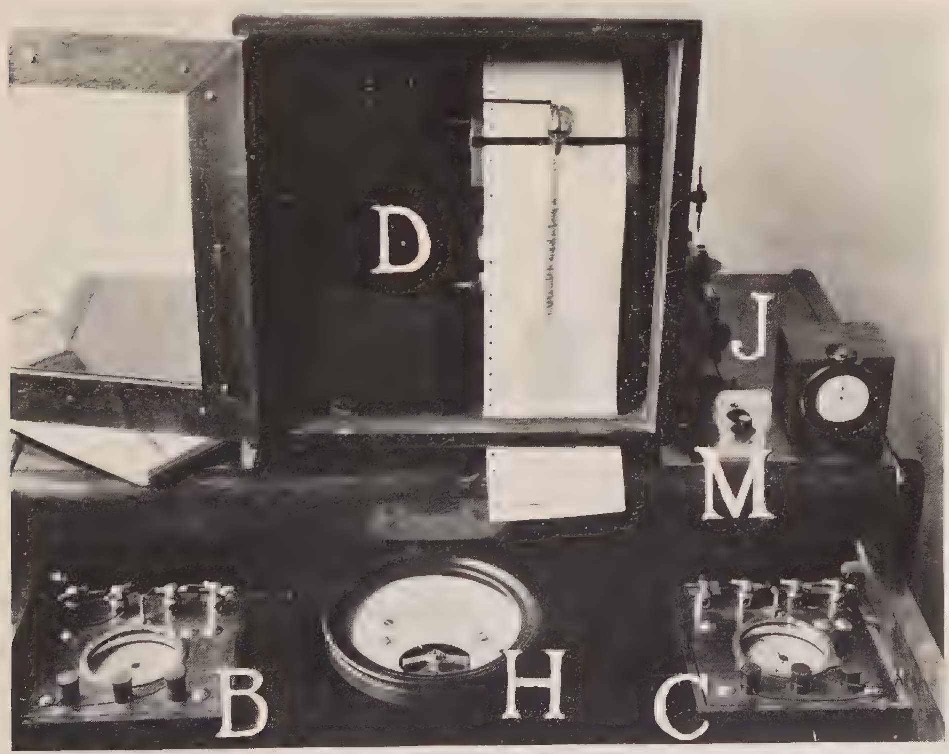

FIG. 5.—Arrangement of Integrating and Recording Features of the Pursuitmeter.

The disturber unit is mounted below these and inside the cabinet, which, without disconnecting the circuits, may be closed up compactly when not in use. *D*, curve-drawing wattmeter; *J*, rheostat; *M*, switch; *B* and *C*, integrating meters; *H*, voltmeter.

the scale is the zero position upon which the reactor tries to hold the needle, the ideal position being that shown in figure 4; no other marks appear on the scale. Subjects are uniformly instructed to keep the white diamond as nearly as possible exactly in register with the white mark. The coordination is a natural one, since the slider of the rheostat is to be moved in the direction the subject wants the needle to move. The slider on the rheostat can be moved with very great ease and delicacy. The compensation is with one hand, by a whole-armed movement, that is, without the elbow resting on the table. The portion of the sliding member of the rheostat to be grasped by the fingers is of large surface and of such shape as to be comfortable during long periods of manipulation. Heating never becomes troublesome.

The integrating and recording instruments and also the disturbing mechanism are built into a cabinet which is 80 cm. high, 70 cm. wide, and 40 cm. deep. The upper part of this unit showing the faces of the meters and the general arrangement may be seen in figure 5. The curve-drawing meter *D* is located on the top of the cabinet, together with the rheostat *J* and the switch *M*. The latter connects the potential sides of the integrating meters and so starts the test from zero position of the meters as well as stops the test for an accurate reading of the meters when desired. The integrating meters, *B* and *C*, which are known as portable test meters, are each fitted with zero set-back arrangements. These instruments are secured on the two doors of the cabinet; the dial of each meter is 6 cm. in diameter and divided into 100 divisions, easily legible. The moving element is an aluminum disk on the vertical shaft; to this a large hand is attached which indicates directly each revolution of the shaft. There are two small dials, as in usual meters, to record the number of revolutions of the large hand.

In order that the integrated score should be accumulative, it was necessary to provide some delicate and effective arrangement allowing each meter to turn in one direction only. For this purpose each integrating meter was equipped with a small hair-spring ratchet device. On the armature shaft was mounted a brass wheel, 12 mm. in diameter, and 1 mm. thick, on the periphery of which 300 teeth have been accurately cut. A counterbalanced pawl is kept in delicate contact with the periphery of the wheel by a hair-spring with adjustable tension. The pawl has but very slight backlash. An adjustment was provided so that the zeroizing of the integrating instrument would not harm this delicate ratchet device. Since the scale on the dial of the test meter is graduated in 100 parts, each part corresponds to three teeth on the ratchet wheel. This degree of exactness in accumulating the small errors in the compensation of the task is wholly satisfactory, as even our best practiced subjects usually allow separate movements of the integrating meter of from 2 to 8 divisions on the scale.

The disturber mechanism is an induction unit with a tapered soft-iron core mounted in such a way that the core may be moved vertically in and out of the spool on which is placed the winding of something over 1,400 turns. It is thus relatively permanent and independent of any changes from wear in long periods of use. The operation of the disturber can most easily be understood from figure 6. The tapered iron core *C* is nearly counterbalanced by a weight *J*. It is suspended and caused to move up and down by a cord which passes over *H*, over *K′*, around *M′*, and finally attaches to *L′*. These points (with the exception of *H*) are all different eccentrics, each operated by an independent countershaft. Each countershaft is rotated at a different speed. The three eccentrics are not only of different speeds, but move the core different amounts. Therefore, while each eccentric has a harmonic motion, their periods are such that, when

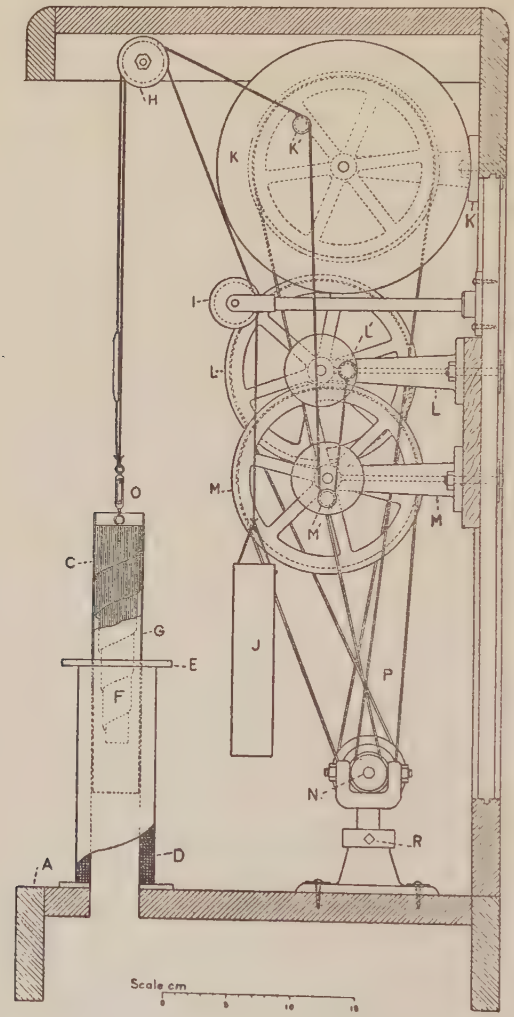

Fig. 6.—Diagram of Disturber Mechanism.

A reactance coil with the laminated iron core so arranged as to be carried through a complicated series of inharmonic motions. *A*, cross-section of cabinet; *C*, soft iron core containing 800 gm. of iron wire, the bundle tapered as shown at *F*, and incased in a fiber tube *G*; *E*, brass spool carrying a winding indicated by *D*; this winding is in circuit, as seen at *E* in figure 3; *O*, turnbuckle; *H*, supporting pulley; *I*, counterweight pulley; *J*, counterweight of about 650 gm.; *K*, *L*, and *M*, three independent countershafts; *K′*, *L′*, and *M′*, three eccentrics; *P*, belts; *N*, driving pulleys and shaft hanger adjustable at *R*. The driving motor is not shown.

taken in combination, they produce an inharmonic series which requires 8 or more minutes to run its course and, in fact, seems never to repeat itself completely. The curve-drawing wattmeter plots the series of changes. These can be seen, natural size, i. e., with no attempt at compensation, in part *B* of figure 20. (See p. 161.) Sections *A* and *C* of this figure represent the tracings when a subject is trying to counterbalance the series of disturbances which constitute the task.

When a subject manipulates the rheostat to compensate the fluctuations, he, of course, disturbs the whole series, and if he is trying to anticipate the deflections by memory, he is certain to lose himself soon after he begins compensation. Hence, when he is actively engaged in the test, he can not anticipate the frequency, direction, speed, or amplitude of the change. The needle moves and stops about 20 times in a minute, and a majority of these changes are in the opposite direction from the preceding movement. Whenever the needle is off the zero position, electric current is integrated in one of the meters in proportion to the time and distance. It is impossible to hold the needle quiet in the zero position, for it keeps crossing back and forth, and the inadequate compensation is constantly accumulated in the two integrating instruments. The most successful subjects make smooth movements rather than jerky, extreme compensations. In our experiments the test period was 5 minutes in length. Since the integrating instruments do not strictly measure the amperage which passes through them, but record only a difference in the amperages of the two fields, the revolutions and fractional revolutions recorded on the integrating meters are used as an expression of the score.

Other instruments were tried in combination with the pursuitmeter to secure a basis for giving the score in common electrical terms or units. Since, in this case, we are not dealing with a simple clear-cut neuro-muscular process, the actual value is of minor importance, our interest being in comparative scores made when the instrument has been standardized similarly and the task kept uniform from period to period and from day to day, as well as from subject to subject. Scores made on the pursuitmeter may be described in terms of the characteristics of the apparatus. In the task which was adopted as standard, the slider of the regulator was placed at a median position, so that the deflections on one side were of equal amplitude with those on the other. A continuous run of 5 minutes without any subject operating the instrument, but with the slider quiet in this one position, gave exactly 20 revolutions of each integrating meter, or a sum of 4,000 revolution units, in which the 0.01 part of a revolution on an integrating meter is taken as the unit. In test runs, which were made each day in connection with the regular measurements, the pursuitmeter seldom gave a deviation from this standard performance of more than ± 0.5 per cent. It is rarely that an adult performance is so poor as to allow the meters to accumulate in a 5-minute period a total of 2,000 points, which represents one-half the standard accumulated when the instrument has no intelligent compensation or direction. A score of 600 points, i. e., three complete revolutions of each integrating meter, is a very good record and represents substantially the equivalent of a deviation of 5 mm. for as much as 2 minutes of the test period. Usually the two meters do not read alike, as the subjects are not equally expert or careful on both sides.

So far as is known, there is nothing about this apparatus which makes it poorly adapted to any subject. The task is continuous and calls for constant attending, requiring both quickness and accuracy, but the muscular demands are very slight, the subject is sitting, and can adjust the apparatus for height and visual requirements. The amplitude and duration of all errors are integrated electrically, being accumulated by two meters from which the score is directly read at the end of the test period, with no record that must be measured or computed. The time and accuracy factors are logically and automatically united in one result. Graphic tracings made by the curve-drawing wattmeter were always taken in connection with our experiments, but their chief value was in demonstrating his difficulties to the subject, so that he might the more quickly acquire skill in the test, and to indicate whether there were serious lapses in attention. The pursuit-meter was used in the experiments described in Chapters V and VI.

STATIC EQUILIBRIUM.

While unsteadiness of gait and of standing posture is the symptom most usually associated with alcoholic intoxication, yet this characteristic sign of the effect of alcohol on motor control seems never to have claimed much attention in laboratory studies on the influence of moderate amounts of alcohol.[a] The "Romberg sign" was early recognized as of special importance in certain diseases and has been used in various forms, but mostly as a clinical diagnostic symptom. It was a natural development that the swaying of the body should be graphically registered, and several investigators, with various interests, arranged simple apparatus for this purpose. In general, a writing-point has been attached to the vertex of the head and a smoked paper suspended above on which the tracing of the swaying movement is recorded. This arrangement is referred to as the "ataxiagraph." It has been used somewhat in psychological laboratories by those interested in the motor ability of children, and has also found some military uses.

Such a graphic record for the swaying movement of the body during a given period offers three chief features for measurement: (*a*) extreme scatter or range of area covered, (*b*) actual length of the path traversed, and (*c*) number of movements or rate of oscillatory movement. Probably the best score for the test would be a proper combination of all three features. The tracings are so intercrossed and complicated that even strong magnification does not make it possible to determine the true length of path or rate of oscillation. Hence the extreme range of movement along the anterior-posterior axis and likewise for the lateral axis are the two measurements usually given. Psychologically, the test is one of standing motionless. When there is no special strain or loss of equilibrium, the subject tries each moment to avoid swaying rather than to return to a starting-point or central position for the location of which he has no accurate criterion. The extreme range of the tracing is therefore a somewhat incidental feature. Most swaying movements occur within an area much smaller than the extreme range.

A mechanical means of automatically summing up all movements of whatever size in terms of their anterior-posterior and lateral components appeared to us as desirable. The ataxiameter which was developed at the Nutrition Laboratory for this purpose has been in use since 1919 and has proved itself a practical means of recording static equilibrium in this quantitative way.[a] The name differentiates it from the ataxiagraph, although, as shown in figure 7, a means is provided for taking graphic records if desired. In this ataxiameter, a square wooden frame *D*, 61 cm. in outside dimensions, and adjusted vertically, is secured at any desired height by two clamps, *F*, *F*. On each corner of this frame a movement adder is mounted. (See side elevation in *B* and end elevation in *C*.) From a collar *Q*, which connects with a headpiece worn by the subject, four silk threads pass, one to each of the four movement adders. Each thread passes over an aluminum pulley which is 180 mm. in circumference, at the bottom of the groove. This groove is wide and smooth. Secured to the same shaft is a larger thin aluminum pulley, the periphery of which is knurled and covered with a rubber band. Two small pawls, *X* and *X′*, are arranged so that they may engage with the rubber surface. One pawl, *X*, is always in

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[a] Immermann (Arch. f. klin. Med., 1866, **1**, p. 595) gives one illustration of the swaying after taking alcohol. Hinsdale (Am. Journ. Med. Sci., 1887, **93**, p. 478) reports having made a trial of registering station when ether was taken while the subject stood in position. Recently Hammarsten and Liljestrand (Bil. A. till Staten offentliga utredningar, Stockholm, 1922, **37**, p. 119) required their alcoholized subjects to walk a narrow raised path at specified rates.

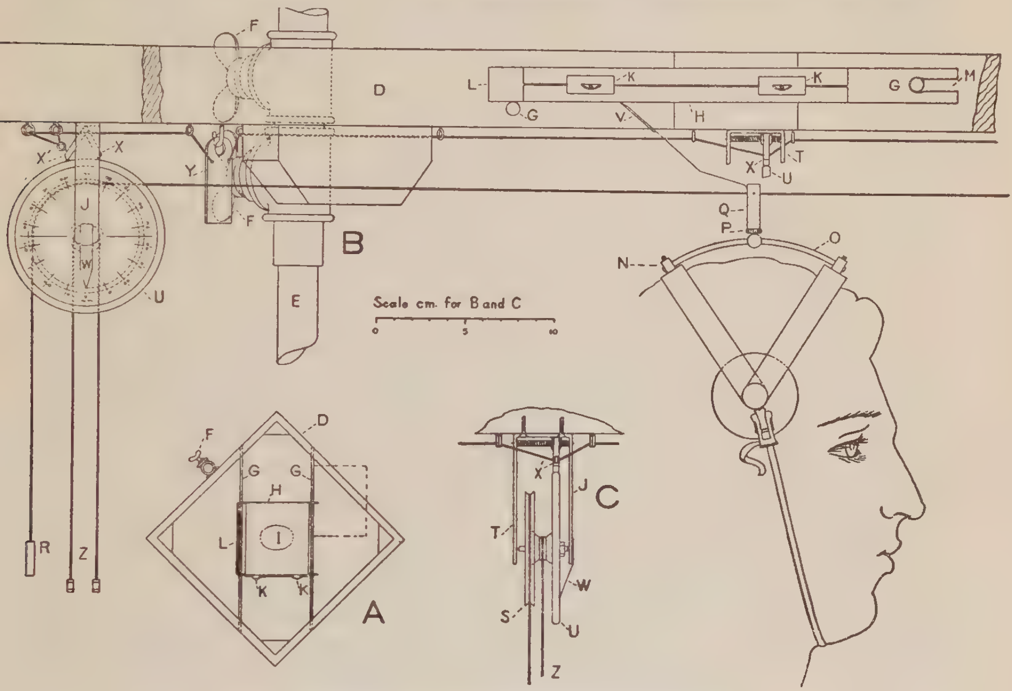

FIG. 7.—Schematic Diagrams of the Ataxiameter.

An apparatus for measuring the swaying of the body when a man tries to stand motionless. *A*, schematic arrangement of frame and support for smoked paper; *B*, side elevation of frame, graphic recording features, and one movement adder; *C*, end elevation of movement adders; *D*, frame; *E*, pipe support; *F*, *F*, clamps; *G*, *G*, rods to support frame *L*, with smoked paper *H*, kept taut by *K*, *K*; *M*, slot in *L* to allow horizontal movement and vertical position (see dotted line in *A*); *N*, headpiece; *O*, curved bar for adjustment of stud *P*, to receive the collar *Q*, carrying writing-point *V*; *J*, *T*, support for pulley unit, *S*, *U*; *W*, reading index; *R*, 5-gram weight on silk cord; *Z*, revolution counter; *X*, accumulating pawl; *X′*, locking pawl; *Y*, weight to release locking pawls.

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[a] Miles, Journ. Industr. Hygiene, 1922, 3, p. 316.

contact with the pulley; thus, when the body sways backward, for instance, the pawl holds firmly and the silk thread drawn by a 5-gram weight *R* slips easily in the groove of the pulley, taking up all slack and making ready instantly to register and accumulate any movement in the forward direction. Movements as small as 0.5 mm. will be positively recorded. When both pawls are in contact, as in figure 7, during the preliminary adjustment of a subject to the apparatus, the silk thread can not turn the pulley in either direction and all of the adders remain zeroized until the moment of actually starting the test. When the test is begun, the weight *Y* is unhooked and dropped at the moment of starting the stop-watch. This releases all four locking pawls so that each adder may turn freely in one direction. When the weight is replaced, all of the adders will be locked into the position which they have reached at the end of the test. The graduations on the scale of each movement adder represent millimeters and the reading is in reference to the index *W*. The cord *Z*, which passes over the shaft, indicates the number of revolutions by the separation of the two small weights caused by the turning of the movement adder. The cord is divided into colored sections for indicating the revolutions, but this feature is not shown in the figure.

The arrangement for the graphic records includes a delicate writing-point *V*, attached to the collar, which is connected with the silk threads and fits on to the headpiece worn by the subject. This writing-point is in delicate contact with the smoked paper *H*, carried on the frame *L*. This frame rests on the two rods *G*, *G*, and may be adjusted laterally. Graphic tracings were usually taken in the experiments, and some use of these is made in considering the alcohol effect on the gross area of sway.

The sum of all four readings of the movement adders is not the exact length of the path of sway, but represents all the anterior-posterior and lateral components of these movements. This total millimeter score is the one which we have used as the significant measure in this test. The measurement covered a period of 2 minutes, during which the eyes of the subject were closed, although he was not blindfolded. The feet were in V-position, i. e., heels together, with inside lines of feet at an angle of 45 degrees, the position being prescribed by small cleats secured to the floor. The body attitude was somewhat better balanced and more comfortable than the characteristic military "attention" position. The apparatus is noiseless. Distracting stimuli were carefully guarded against, and such influencing conditions as footwear kept uniform. The test is one which does not seem to be markedly improved by practice, and the data obtained are among the most trustworthy secured in these studies.

The station test was used in the two studies in which doses of very dilute alcohol were given. The discussion of the results may be found in Chapters V and VI, on pages 135, 183 et seq., and 238, and illustrative graphic records appear in figure 11, page 139. The method of measuring these records for area of sway is also described on page 140.

JOHNSON CODE (SUBSTITUTION TEST).

For study of the psychological effects which result from deprivation of oxygen, Dr. H. M. Johnson[a] arranged a series of code tests which were used in our investigation of the effects of dilute alcohol. The nature of the material and the form of the test may be illustrated as follows:

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[a] Johnson and Paschal, Psychobiology, 1920, 2, p. 193.

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
P X G Z D K M B T F O E A Q L U Y J V H N I R C S W
D J E A S R N U M V   P X H Y I T G L Z W   O K C Q F B G P I X
W V U Q N C E O Y M   K Z D T F S B G A R

The first line is the alphabet in the usual order with A at the extreme left and Z at the extreme right. The second line is the code, while the five short lines, made up of 10 letters each, represent the material to be transliterated. Twenty cards were prepared on which was printed the alphabet, a code, and 50 letters of material to be transliterated. The preparation of these different codes and of the material to be codified requires great care in order to produce tests of equal difficulty. In preparing this material, Doctors Johnson and Paschal adopted certain rules, as follows:

(1) No code is systematically derived from another.

(2) Every letter in the alphabet shall be represented by a different letter in the code.

(3) No letter in the code is to be substituted for its immediately preceding letter in the alphabet.

(4) Habitual sequences (e. g., O K, Q U, etc.) are to be avoided, as are also sequences leading to the formation of considerable parts of words.

(5) A given letter is not to be substituted for the same letter more than twice in the 20 codes.

With these limitations, the sequences of the letters in the various codes were determined by shuffling a pack of prepared cards. The code having been prepared, a set of work material constituting 50 letters was made up by shuffling two alphabets to determine the sequence. This done, the original set was transliterated into code 1 and the result into code 2, and this in turn into code 3, etc. By these methods a group of 20 sets of tests have been derived which appear to be of practically identical difficulty. The various test cards were given to the subjects in an irregular order, and they were not numbered in such a way that they could be identified. The codes were too numerous and too nearly alike to be memorized by the subject.

In the experiment, a test card attached to a sheet of ruled paper on which the transliterations were to be written in an orderly manner in prescribed squares was placed before the subject as he sat at a desk, but it was kept covered until the signal was given to begin the work. The subject wrote with a pencil and used a stylus in the other hand to aid him in keeping his place. The object was to transliterate correctly the 50 letters of material as quickly as possible after the beginning signal. An assistant timed the performance with a stop-watch. Most of the subjects, after their preliminary trials, adopted the method of taking the material in 2-letter groups rather than a letter at a time and following it entirely through before reading the next letter to be transliterated. The sheet on which the subject wrote provided 5 lines of 10 squares each. If the subject discovered at the end of a line that he had made an error, the instruction was to make no attempt at correction or location of the error, but to proceed. The actual test usually required approximately 2 minutes. Of course, this is a very short test from which to expect to get regular and consistent results. The occurrence of one error which the subject may perhaps vaguely recognize and which produces a momentary block in the progress of the test may exercise a strong influence on the result of such a brief measurement. A better method of employing the code test would doubtless have been that followed by Johnson and Paschal, who required the subjects to transliterate successive groups of material, and gave him one test card after the other, but our experimental cycle of 30 minutes was not long enough for this.

The code test was used only with the trained subject, and the group of young men to whom very dilute alcohol was given. The results obtained are discussed on pages 168, 183 et seq., and 254.

CHAPTER II.

INFLUENCE OF ALCOHOL ON TYPEWRITING EFFICIENCY AND SIMPLER RELATED ACTS.

GENERAL PLAN OF TYPEWRITING EXPERIMENTS.

At the inception of this investigation, September 1915, certain problems were in mind for which objective answers were desired. Dodge and Benedict[a] from their research concluded that the effect of alcohol on the coordination processes varied directly with the dose, came closest to the total average of all the tests, covered the most general characteristics of the alcohol effect, and came nearest to being a measure of the individual's susceptibility to alcohol. However, the coordination processes which they measured as indices of the effect of alcohol were considered primarily from the standpoint of speed, as the records did not lend themselves well to a determination of the accuracy of coordination. This was later pointed out by one of their reviewers.[b]

The typewriting series, therefore, followed somewhat the program for alcohol investigation earlier issued by the Nutrition Laboratory,[c] and was planned with a view to providing definite data on both speed and accuracy. The general features of this plan were as follows:

Measure of efficiency in coordination.—The first problem was to arrange a series of experiments which should offer ample opportunity for comparing the effects of alcohol on efficiency (speed and accuracy of coordination) and should provide data which could be compared with those obtained by Dodge and Benedict, and also with the findings in a later series of experiments in which Miles[d] repeated some of their measurements. No act of skill seemed better suited to our purpose than that of typewriting. This as a measure of efficiency in skilled coordination has, among others, the following advantages: (1) It involves a very large number of neuro-muscular habits which are usually carried out with a small amount of gross body movement. (2) Since typewriting is one of the most complicated coordination performances and at the same time a very common form of industrial employment, highly practiced and reliable subjects can be secured for purposes of experimentation. (3) The factors of speed and accuracy in the coordination involved in typewriting can be well separated. As a skilled process it is one of the most accessible to experimentation, since it can be performed in the laboratory with no disadvantage. (4) The commercial typewriter is a highly developed, self-registering mechanism which is readily adaptable to any changes desirable in the laboratory or to fit the needs of the individual subject. The records which it provides are definite and have the advantage of possessing distinct human interest. (5) The difficulty of the coordination task to be performed can be kept nearly uniform, or can be varied as desired. The usefulness of typewriting for experimentation in the psychological laboratory has been generally recognized in the last few years and a large number of important studies in the psychology of learning have utilized it, as may be seen from the articles by Swift,[a] Swift and Schuyler,[b] Book,[c] Hill, Rejall, and Thorndike,[d] Bradford,[e] Wells,[f] and Chapman.[g]

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 265.

[b] Rivers, Science, 1916, **44**, p. 102.

[c] Dodge and Benedict, loc. cit., Appendix I, p. 266.

[d] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918.

General course of effect of alcohol.—The experiments of Miles, as well as some of those of Dodge and Benedict, showed that the alcohol effect tended to diminish 3 hours after the ingestion of the dose, but it could not be proved whether this was due to a natural diminution in the effect of the alcohol on the nervous system or whether it was associated with something in the nature of an increased effort at the end of the experiment. It was determined in the present series to extend some experiments over a period of 5 hours, so that, if possible, the changing amount of the effect of alcohol could be depicted with greater assurance.

Influence of food.[h]—The third problem was the influence of food on the effect of alcohol. That alcohol taken with food or shortly after a meal should be more slowly absorbed into the blood-stream seemed only reasonable, and, indeed, had been shown in some experiments with animals. However, to our knowledge experiments had never been carried out with human subjects in which psychological measurements were made and the food factor systematically varied.

Repetition experiments.—The series of experiments in which Miles[i] repeated and extended the observations made on one of the subjects used by Dodge and Benedict yielded results which established the importance of repetition in such investigations. It is highly important to discover whether the same subject in two separate series of tests shows substantially the same results. Repetition series on the same individual, of course, bring in the problem of tolerance for the alcohol, as well as emphasize the changes that may develop as a result of learning. Series of repetition experiments were made with three of our subjects, *Roj, Fam,* and *Mih.* With one man, *Roj,* the food factor was kept constant, but the duration of the experimental day changed, being a 3-hour session in one series and in the other a 5-hour session. With the other two subjects (*Fam* and *Mih*) the duration of the experimental day was constant but the food factor changed.[j]

Approximately one-half of a subject's time was occupied in actual typewriting, the other half in performing tests of simpler related processes. This variety not only served to make the work less fatiguing and to maintain the subject's interest, but added considerable supplementary evidence to that found for the effects of alcohol on the typewriting efficiency.

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[a] Swift, Psychol. Bull., 1904, **1**, p. 295.

[b] Swift and Schuyler, Psychol. Bull., 1907, **4**, p. 307.

[c] Book, The psychology of skill, Univ. Montana Pub. in Psychol., Missoula, 1908, **1**, pp. 1-188.

[d] Hill, Rejall, and Thorndike, Pedagogical Seminary, 1913, **20**, p. 516.

[e] Bradford, Pedagogical Seminary, 1915, **22**, p. 445.

[f] Wells, Am. Journ. Psychol., 1916, **27**, p. 47.

[g] Chapman, Journ. Applied Psychol., 1919, **3**, p. 252.

[h] The two series in which food was taken immediately before the experiments (*Fam* I and *Mih* I) are discussed in Chapter III. (See p. 102.)

[i] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918.

[j] The repetition experiments are discussed in Chapter III. (See p. 96.)

SUBJECTS OF EXPERIMENTS.

The individuals serving in these experiments were five young men, all of whom had taken regular courses in typewriting and stenography, and who had served one or more years as stenographer and typist in various business offices. Three of the men were obtained through employment agencies. With these (*Roj*, *Lig*, and *Suf*) the experiments could be made in the morning. The other two subjects (*Fam* and *Mih*) had regular employment, but their work was sufficiently lax for them to take on the extra service in the evening after regular office hours. All were paid somewhat liberally on an hour basis for the time which they spent at the Laboratory, with the understanding that they were to do the best work of which they were capable. Certain information as to their habits, as well as physical data, etc., are appended here:

Fam.—Age, 23 years; height, 163.9 cm.; average body-weight, 52.6 kg. Moderate user of wine and cocktails, also tobacco (cigars). Touch operator.

Lig.—Age, 26 years; height, 170.2 cm.; average body-weight, 67.6 kg. Moderate user of beer, but recently abstinent; also uses tobacco (cigarettes). Touch operator.

Mih.—Age, 23 years; height, 190.5 cm.; average body-weight, 74.9 kg. Moderate user of beer, also tobacco (pipe). Touch operator.

Roj.—Age, 23 years; height, 165.1 cm.; average body-weight, 51.0 kg. Moderate user of beer, also tobacco (cigars). Touch operator.

Suf.—Age, 23 years, height, 160.0 cm.; average body-weight, 47.9 kg. Moderate user of whiskey, also tobacco (cigarettes). Not a touch operator.

It will be noted that all of these subjects were moderate users of alcoholic beverages, mostly in the form of beer. In the preliminary interview with each man it was ascertained if he had objection to taking moderate amounts of alcoholic beverages in connection with an experiment in typewriting. The alcohol feature of the experiment was not especially stressed in these conferences. It was implied to the subject that a certain amount of alcoholic beverage would be given him each day in connection with the experiment, but that probably he would feel very slight, if any, effect from the dose. Such matters as the control of his food, the use of tobacco,[a] regular hours for sleep, and of regularly working at his best efficiency in the tests were stressed as of chief importance. No mention was made of the control doses or of preliminary practice experiments.

Throughout the period of their employment in connection with these experiments, all of the men showed themselves as thoroughly willing and cooperative and, so far as could be judged from observing them at work, they made remarkably consistent efforts to hold themselves unremittingly to the task in hand. As a matter of precaution, each man at the termination of his work was asked to fill out an affidavit which should give information regarding the use of alcohol outside of the Laboratory, etc. These affidavits reveal no exceptional condition which should be taken into account in the interpretation of the data. The subjects were also encouraged to give their impressions regarding the effect of the daily dose on their efficiency in performing the tasks set them. Their comments are recorded in the Appendix, page 277.

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[a] Tobacco was used by the subjects as follows:

Roj. Two cigars per day following each experiment. No tobacco with or following morning meal which preceded the dose in *Roj* I by about 3 hours.

Lig. One cigarette following each meal of the day. The cigarette following breakfast was separated from the dose by about 2¼ hours.

Suf. One cigarette following each meal of the day. The cigarette following breakfast was separated from the dose by about 2¼ hours.

Fam. Usually smokes two or three cigars daily, but no cigarettes. Smoked one cigar after the noon meal but no more until after the experiment. The time between the smoking of the cigar and the dose was approximately 6 hours.

Mih. Smoked one pipe after the noon meal, i. e., about 6 hours before the dose.

GENERAL DATA REGARDING EXPERIMENTS.

This series of 44 experiments was carried out between September 21, 1914, and June 25, 1915. Table 1 presents the chronological arrangement and gives information useful in interpreting the results, such as the average body-weight, the time of day when the experiments were made, the number of periods (that is, the number of repetitions of measurements on that day), the number of hours intervening between the end of the last meal and the ingestion of the alcohol, the estimated energy content of the previous meal in calories, and the volume, amount, and concentration of the alcoholic and control doses employed.

Preliminary Training of Subjects.

Usually on the first day that a man served as a subject he went through the series of measurements two or three times. During these tests he was carefully instructed and encouraged to go slowly, so as to understand thoroughly what was expected of him. The apparatus was adjusted to him in every way possible to make his work comfortable and natural. A control dose was given regularly on the first day. On the second day adaptation was more complete and 4 or 5 periods could be accomplished. The smaller alcohol dose, that is, 21 to 28 grams of ethyl alcohol, was used on this day. The sessions on both these days were not so long as on the following days. From the experimenter's point of view, these two days are considered wholly as practice experiments and the results are not included in any of the succeeding tables which contrast the efficiency on alcohol and non-alcohol days. Of course, no subject that served had any hint that the first two days were intended only to initiate him as thoroughly as possible into our laboratory routine. The discarding of these results may seem wasteful, but it must be recalled that individuals, though practiced in typewriting involving usual correspondence and business forms, will still require time for adaptation to what might be termed a "new line." Aschaffenburg[a] discovered that his well-practiced typesetters, even in their natural environment, made rapid improvement when placed under experimental conditions. Some of the results for the first alcohol day, particularly those which involve the non-voluntary functions, have a certain worth, and could probably be used as indicators of the effect of alcohol. However, in planning these experiments, it was thought that comparisons would be more sharply defined and the presentation much less complicated if the results on the first normal and first alcohol days were wholly disregarded and the comparison based on the next four days, on two of which alcohol was given in different amounts. With *Roj* but one week intervened between the last day of his first series

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[a] Aschaffenburg, Psychol. Arbeit., 1896, 1, p. 608.

TABLE 1.—*Chronology and general data for the experiments on alcohol and typewriting efficiency.*

Subject and average body-weight.	Date.	Type of experiment.	Experiment began.	Experiment ended.	No. of periods.	Time between dose and last food.[1]	Estimated energy of meal.[2]	Total volume of dose.[3]	Alcohol by weight.	
									Amount.	Concentration.
	1914		*a. m.*	*p. m.*		*hrs.*	*cals.*	*c. c.*	*gms.*	*p. ct.*
Roj (I)[4]	Sept. 21	Control	8^h50^m	12^h00^m	[5]2	4¼	770	100	....	....
(51.0 kg.)	Sept. 22	Alcohol	8 55	12 00	[5]4	3¼	770	108	24	22
	Sept. 23	Control	9 05	12 10	5	2½	770	100	....	....
	Sept. 24	Alcohol	9 00	12 05	5	3	770	108	24	22
	Sept. 25	Control	9 05	12 00	5	2¾	770	[6]101	....	....
	Sept. 26	Alcohol	9 00	12 00	5	2½	770	159	35	22
Lig	Sept. 28	Control	9 10	12 15	[5]2	4½	1,090	100	....	....
(67.6 kg.)	Sept. 29	Alcohol	9 00	12 20	[5]5	3	1,090	108	24	22
	Sept. 30	Control	8 00	1 01	8	2¼	1,090	100	....	....
	Oct. 1	Alcohol	8 15	1 30	10	2	1,090	108	24	22
	Oct. 2	Do.	8 05	1 30	10	2	1,090	[6]159	35	22
	Oct. 3	Control	8 05	12 45	8	2½	1,090	101	....	....
Roj (II)	Oct. 5	Do.	8 15	12 45	8	2¾	900	100	....	....
(51.1 kg.)	Oct. 6	Alcohol	8 10	1 15	10	2	770	108	24	22
	Oct. 7	Do.	8 10	1 20	10	2	770	[6]159	35	22
	Oct. 8	Control	8 05	1 15	10	2	770	101	....	....
Suf	Nov. 2	Do.	9 00	12 15	[5]2	3¾	1,060	100	....	....
(47.9 kg.)	Nov. 3	Alcohol	9 05	12 25	[5]5	2½	1,120	108	24	22
	Nov. 4	Control	8 00	12 40	7	2½	1,120	106	....	....
	Nov. 5	Alcohol	8 00	12 55	9	1¾	1,120	108	24	22
	Nov. 6	Do.	8 00	1 25	9	2¼	1,120	158	35	22
	Nov. 7	Control	8 00	12 45	8	2	1,120	106	....	....
	1915		*p. m.*							
Fam (I)[4]	Mar. 22	Control	6^h40^m	9^h00^m	[5]2	1¾	[7]1,070	[6]156	....	....
(53.3 kg.)	Mar. 23	Alcohol	6 30	9 45	[5]4	1¼	[7]1,935	151	21	14
	Mar. 24	Control	6 30	11 25	8	¾	[7]2,100	150	....	....
	Mar. 25	Alcohol	6 40	11 10	8	¾	[7]1,890	151	21	14
	Mar. 26	Do.	6 40	11 15	8	¾	[7]1,860	151	32	21
	Mar. 27	Control	6 45	11 00	8	¾	[7]1,850	[6]151	....	....
Mih (I)[4]	Apr. 19	Do.	6 00	8 45	[5]3	1¼	[7]1,410	151	....	....
(76.0 kg.)	Apr. 20	Alcohol	6 05	8 45	[5]5	¾	[7]1,810	150	26	17
	Apr. 21	Control	5 50	11 00	10	¾	[7]1,210	150	....	....
	Apr. 22	Alcohol	5 50	10 50	10	¾	[7]1,660	200	28	14
	Apr. 23	Do.	5 49	10 45	10	¾	[7]1,550	200	42	21
	Apr. 24	Control	5 55	10 37	10	¾	[7]1,650	200	....	....
Fam (II)	June 9	Do.	5 45	9 40	[5]7	3¼	470	151	....	....
(51.9 kg.)	June 10	Do.	5 45	9 35	8	3	470	151	....	....
	June 11	Alcohol	5 40	9 30	8	3	470	151	21	14
	June 12	Do.	5 00	8 45	8	2¾	470	[8]161	32	20
	June 13	Control	5 00	8 50	8	2¾	470	151	....	....
Mih (II)	June 21	Do.	5 35	9 40	[5]7	5¾	1,750	151	....	....
(73.8 kg.)	June 22	Do.	5 30	9 35	9	5½	1,265	151	....	....
	June 23	Alcohol	5 35	9 30	9	5½	1,680	151	28	19
	June 24	Do.	5 25	9 25	9	5½	1,190	201	42	21
	June 25	Control	5 25	9 15	9	5½	1,370	151	....	....

[1] Time from completion of meal to completion of drinking the dose for the day.

[2] The meal which preceded the experiment. For data regarding use of tobacco on the experimental days, see p. 31. footnote *a*.

[3] Each control or alcohol dose contained 7 c. c. of Rivers's orange infusion and 1 c. c. of saccharine solution in addition to the water or water and alcohol. The alcohol solution used in making up the dose contained 23.6 grams of absolute ethyl alcohol per 100 c. c.

[4] The results of the experiments in the first series with Roj. Fam, and Mih are discussed in Chapter III, p. 96, as the discussion in Chapter II refers only to experiments with like conditions.

[5] The experiment on this day was devoted to practice in the tests and general routine and these results do not appear in our comparison.

[6] In addition to the usual ingredients, the dose contained 1 c. c. of quassia infusion.

[7] Hearty evening meal at the Laboratory immediately before starting experiment.

[8] The subject complained of the taste left in his mouth and was given 20 c. c. of water.

and the beginning of his second series; it was accordingly not deemed necessary to preface his second series by practice days, but this would have been desirable.

NUMBER OF PERIODS IN AN EXPERIMENT.

Aside from the first two days, the subject usually accomplished from 8 to 10 periods or cycles in an experimental day, the session continuing 3½ to 5 hours. In addition, there were certain preliminaries to be gone through with before the experiment actually began, especially in the first series with *Fam* and *Mih* (*Fam* I and *Mih* I) who came to the Laboratory and ate their evening meal before the beginning of these experiments. The number of periods varied considerably with the different experimental days. *Roj* in the first series (*Roj* I), when the sessions were 3 hours long, accomplished regularly 5 periods each day. For purposes of comparison it is, of course, desirable that every man should have the same number of periods, that is, if the results are to be averaged in a group table. Practically it is very difficult to arrange the experiments so that they will be within identical time limits for all of the men.

FOOD CONDITIONS AND DOSAGE.

The alcohol or control dose was given after the first experimental period of any particular day. The amount of time between the completion of the last meal and the ingestion of the alcohol varies in table 1 from 45 minutes to 5¾ hours. In the case of *Fam* I and *Mih* I, the object was to precede the experiment by a meal, so that the stomach would contain a large amount of food at the time the alcohol was ingested. The 45 minutes allowed just enough time to make some preliminary adjustments and to complete the first period. When the food was taken at the Laboratory immediately preceding the experiment, the quantity ingested was carefully weighed. The amount of food actually ingested on these occasions was the equivalent of a heavy meal, and consisted of beefsteak, potato, bread, butter, and milk.[a] In contrast with these experiments, in which the food immediately preceded the alcohol, or as nearly so as could be, we have the second series of experiments (*Fam* II and *Mih* II). With *Fam* a small meal was taken practically 3 hours prior to the alcohol, while with *Mih* a large meal was taken 5½ hours before alcohol. For a general comparison of typewriting efficiency, it will be possible for us to group five of the men as follows: *Lig, Roj* II, *Suf, Fam* II, and *Mih* II. In these five instances the food was usually not very large in amount and was separated from the taking of the alcohol by at least two hours.[b]

The average body-weights of the subjects in the different series (see table 1) range from 47.9 to 76.0 kg. These variations in gross body-weight are of importance in comparing the effect of alcohol on different individuals. In the experiments made in 1914, all three men (*Lig, Roj,* and *Suf*) were given identical alcohol doses. Each control or alcohol dose contained 7 c. c. of Rivers's orange infusion[c] and 1 c. c. of saccharine solution in addition to the water, or water and alcohol, and in some cases the dose contained 1 c. c.

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[a] See Chapter III, p. 102, for discussion of these experiments.

[b] For use of tobacco by subjects, see p. 31, footnote *a*.

[c] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 22, note 2.

of infusion of quassia. Quite regularly the concentration of the dose was 22 per cent by weight, and doses of two sizes were used, i. e., 24 and 35 grams. Thus, the larger dose contained 50 per cent more alcohol than the smaller, but both are within the limits of what are commonly accounted as moderate amounts of alcohol.[a] Dodge and Benedict[b] used 24 and 36 grams of alcohol and designated these as doses A and B. The total volumes were 150 and 225 c. c., respectively, i. e., about 17 per cent alcohol by weight. Our doses were slightly stronger in concentration. In the experiments of 1915, the smaller dose, A, was adjusted substantially on the basis of body-weight, about 0.5 c. c. of absolute alcohol per kilogram of body-weight being given. (See table 1, p. 33.) As the amount of alcohol in dose B was 50 per cent more than that in dose A, *Fam* received in doses A and B 21 and 32 grams, and *Mih* 28 and 42 grams, respectively. In all cases the dosage was taken at room temperature, the rim of the glass was wiped with alcohol to give the odor while drinking, and the ingestion required less than a minute. Subjects were not allowed to take water after the ingestion of the dose or, indeed, during the experimental session, with a single exception noted in the table. This exception was *Fam* in the second series on June 12, who, after the larger dose (32 grams) took 20 c. c. of water, which was given because he complained so insistently of the taste left in his mouth by the alcohol solution.

Program of Measurement.

In arranging the experimental program, efforts were made to meet four conditions which, on the basis of previous alcohol experimentation at the Nutrition Laboratory, seemed desirable objectives. These conditions were as follows: (1) To obtain a sufficient number of results for any one measurement to give a fairly trustworthy representation of the subject's performance in that test; (2) to provide enough variety in the measurements so that the subject would continue to be alert, and onset of fatigue would be delayed as much as possible; (3) to arrange the tests in such a way that they could all be completed in 30 minutes, so that changes in the effect of the alcohol might be investigated by successive repetitions of the series of tests; (4) to select a group of measurements which would supplement one another, and thus aid in the analysis of the effect of alcohol. After a few preliminary trials, the program on page 36 was developed and was adhered to for the most part during the whole series of experiments. Practically the only differences were certain minor additions to the series which were made in some cases.

The measurements were made in the order given on page 36. The pulse-rate for the quiet position usually followed the lid reflex before the subject returned to the typewriting table. He had thus been sitting quiet for some time during the eye-movement and lid-reflex measurements. The series of tests as performed required very nearly 30 minutes for its completion, depending somewhat, of course, upon the efficiency of the subject in the typewriting, this part of the program occupying 15 to 20 minutes.

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[a] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 23, note 1.

[b] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 30 and note 2.

All of the measurements were taken in one room. The apparatus was compactly and conveniently arranged[a] and therefore required but little movement on the part of the subject. The typewriting table was well removed from the recording apparatus and the subject faced a plain dark wall. No one sat or stood near the man as he was writing, and distraction from the experimenter and his assistants, as well as from the apparatus of the laboratory, was minimized as much as possible. Aside from the typewriting, the other arrangements of the laboratory were essentially those which had been previously used by Dodge and Benedict, and also by Miles; hence the apparatus needed no special testing. A very regular technical routine was adopted and only a minimum amount of time was lost by adjustments or difficulties on account of the apparatus. This regularity in operation is attested by the fact that no records are missing for any measurements and none had to be discarded because of technical errors.

Measurement.	Time required, in minutes.
1. Typewriting:	
(*a*) 20 lines of practice sentence at maximum speed	5
(*b*) 25 lines of difficult prose copy	6
(*c*) 10 lines of nonsense 5-letter combinations	5
2. Pulse-rate recorded with the string galvanometer:	
(*a*) With subject quiet for some time preliminary to writing practice sentence	1
(*b*) During typing of last two of the 20 lines of practice sentence	....
(*c*) After 30 seconds of rest, sitting quietly following typing of practice sentence	1
3. Word-reaction time in speaking 4-letter English words	3
4. Finger movement at maximum speed for 8 seconds taken with pulse-rate	2
5. Eye movement: Velocity for movements of 40 degrees	4
6. Protective lid reflex: Latency and amplitude	3
Total time for series of tests within the period	30

TYPEWRITING TASKS.

The typewriting efficiency of the subjects was tested at what might be called three levels of difficulty, as based on the material which each was required to write. It was found that nearly all of the men had a practice sentence which they had employed more or less when learning typewriting, and which they were in the habit of using when trying new machines. This sentence was found to be essentially the same with all the men. Since typewriting is a system of habits, and efficiency is dependent upon the multiplicity of repetitions, it was judged that probably each man could show his maximum speed at fingering if he were required to write this practice sentence; hence 20 or more repetitions of the sentence were made the first typewriting task. The sentence written was essentially "Now is the time for all men to come to the aid of their party." *Lig* shortened it and finished with "come to our aid." *Mih* concluded the sentence with "country" in place of "party," and *Fam* used "brave men" and "country."

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, frontispiece, and fig. 1, p. 31.

It will be observed that this sentence involves mostly very short words, and also that a number of widely distributed letters on the keyboard are absent, so that the fingering is of the very easiest. The instructions given were to "write *accurately* and as fast as possible." The practice sentence made one line of typewriting; therefore each time the sentence was written, besides striking the letters and spaces properly, there was one capitalization, one period, and one carriage movement. The same practice sentence was written each day by the subject throughout the period of his experiment. Hence, in the two preliminary days, each man received considerable practice in writing this sentence before the main part of the study was begun, and several of them practiced it outside the Laboratory with a view to making this part of the test a demonstration of the most rapid typing of which they were capable.

The second portion of the experiment consisted of typing 25 lines (approximately 250 words) of rather difficult prose copy. This material was taken from a scientific article, but contained no formula, data, or tabular matter, so that aside from capitalization, the occasional use of a hyphen, and the common punctuation marks, only the letter keys of the typewriter were involved. Ten sheets of this printed copy were provided by cutting up the original article and using those pages on which the paragraphs were quite long and the discussion seemed to be, as nearly as could be judged, of equivalent difficulty from page to page. Each page of copy was made up of parts of two paragraphs, so that one paragraph indenture was required. The actual number of sentences, and therefore of capitalizations, could not be made constant. The material was printed in 8-point Gothic type and was very legible. The copy was held on an inclined stand which could be located very near the subject and he was free to arrange this stand and the portable electric desk-lamp during the first two days of practice in the way most satisfactory to him. He found on the first or second day the adjustment which he liked best and this was kept constant during the remainder of the experimentation. The pages of prose copy were numbered 1 to 10. In the first period on each experimental day with each subject, page No. 1 was copied, in the second period page No. 2, and so on throughout the experimental day. Hence the performance in period 1 on the different days always involved the typing of the same material, and the same was true of the other periods. There was a certain amount of learning as the experiment continued, the longer words particularly becoming more familiar, but no subject found himself able to memorize the copy. The factor of learning and familiarity with the prose copy seemed a less complicating error than would probably be involved in supplying for each experimental period in the whole series a different piece of copy and assuming that they were of equal difficulty.

The third and last typewriting task was the copying of 5-letter nonsense combinations, 80 of these being arranged in 10 lines of 8 nonsense syllables each. This material may be illustrated in the following line:

yhsrm vblyi ckzbm scige cpofk hvrzy bicbm gfsdc

A sheet of this copy resembled tabulated material, as all of the combinations were of the same length (5 letters) and each line contained 8 combinations. This aided the subject somewhat in keeping his place as he did the typing. No capitalization or punctuation was involved in the task, so that aside from the letter keys and space-bar, but one carriage shift was necessary for each set of eight combinations. Ten pages of such copy were provided and were judged to be of equal difficulty. Page No. 1 was always used in period No. 1, as was page No. 2 in period No. 2, and so on in sequence on both control and alcohol days.

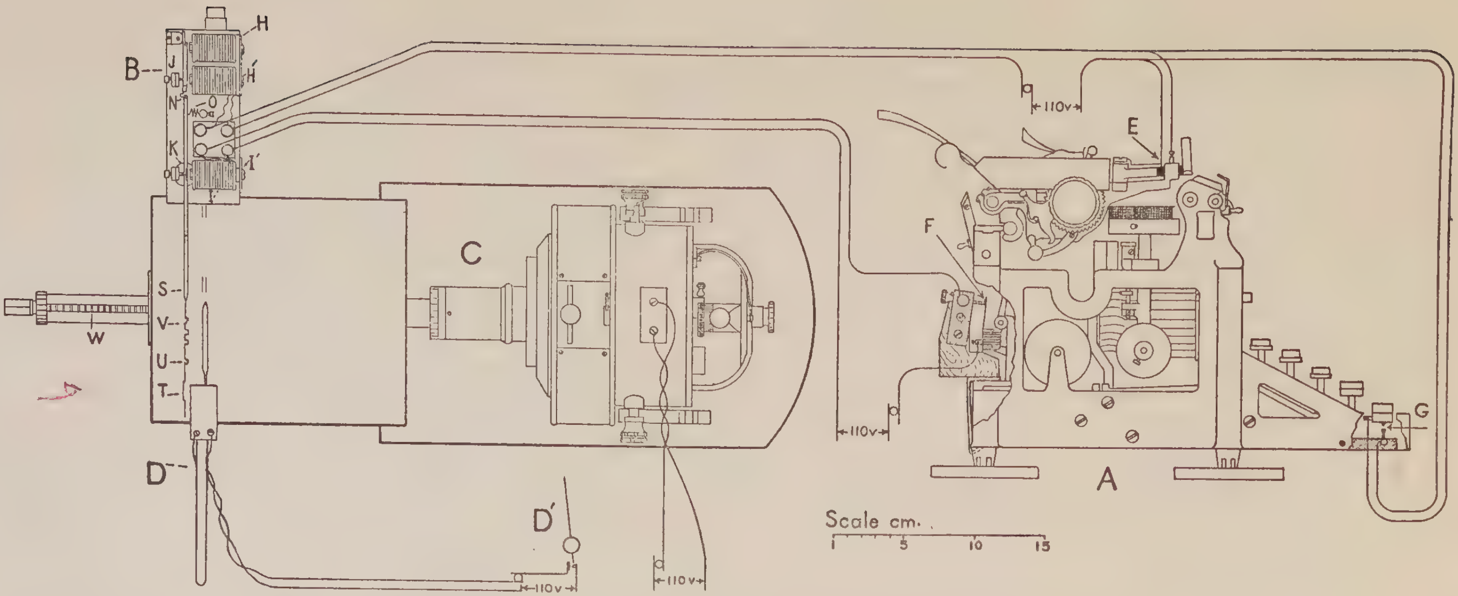
In all three of the typewriting tasks the subject was instructed to write as *accurately* and as fast as possible, and never to correct a mistake. The back spacer for correction of errors was not to be used. This at first occasioned some difficulty, but by the time the two preliminary days were over, the subjects had fairly well adapted themselves to the routine. In transcribing the prose and nonsense, the subjects were instructed to make the typewriting correspond line for line to the printed copy. This was not found to be a hardship. It was, indeed, a simplification for the subject and also for the experimenter in working up the records later.

Technique for Recording Time Relations.

The typewriter automatically provides us with a record of the accuracy of an individual's performance which may be compared with the copy typed. The time relations of the process are in no way indicated on the typed sheet and must be provided for by some accessory apparatus. There are three features in the action of the typewriter or in the process of typewriting which should be distinctively marked on the objective records so that the *time durations* can be ascertained for them separately or in a desired combination. These are: (1) the movement of the lever which spaces the lines and moves the carriage to the right for beginning a new line of typewriting; (2) the action of all typewriter keys which print characters; (3) the action of the space-bar by which the words are separated. The shift key for capitalization need not be recorded separately, as the time for this action can be computed with fair accuracy when it is desirable to secure it.

Since the typewriter has many moving parts and a fairly open framework, it lends itself well to the attachment of contacts for completing electrical circuits. However, it is a matter of some difficulty to get contact arrangements that will *remain* constantly in adjustment and endure the wear involved in long series of experiments with different subjects.

A diagram of the arrangement for recording the time relations of typewriting is shown in figure 8. A side elevation of the standard commercial typewriter which was used in nearly all of our experiments is drawn with certain parts of the frame cut away to expose the contact mechanisms. (See *A* of fig. 8.) Contact *E* was closed when any pressure was exerted on the lever which returned the carriage and also shifted the typewriter roll. One side of this circuit was connected by a small binding-post to the frame of the carriage, while the other was a contact point carried on the movable arm but insulated from it. Contact *F* was located on the rocker-arm associated with the escapement at the back of the typewriter, and was insulated from the typewriter. This contact was closed every time a character-printing key or the space-bar was pressed. It was so adjusted



A, standard commercial typewriter drawn with certain parts of framework cut away to expose contact mechanisms *E*, *F*, and *G*. The printing of any character caused the contact at *F* to be closed. When the space-bar was operated, contacts at *G* and *F* were both closed. The return of the carriage for a new line of typewriting closed the contact at *E*. These three contacts operated electromagnets at *B*, the Dodge duplex marker. The closure of contact *F* completed a circuit through the electromagnet *I* and the invisible magnet *I′*, resulting in the deflection of the writing-point *S* to the right (*U*). Closure of contact *E* completed a circuit through the electromagnets *H* and *H′*, causing the writing-point *S* to deflect to the left (*T*). A pressure on the space-bar closed both contacts *G* and *F*, completing circuits in both magnets, so that the writing-point described a double notch (*V*). The records were made on an electrically-driven kymograph *C*. *W*, spiral for moving the drum of the kymograph. *D*, control time marker, actuated by *D′*, a pendulum interrupting the electric circuit every 2 seconds.

Fig. 8.—Schematic Diagram of Arrangement for Recording Time Relations of Typewriting.

that the carriage could not be moved forward one space unless the contact was closed. Contact *G* was carried on the space-bar and closed whenever the space-bar was operated. This circuit was also insulated from the typewriter frame.

The action of these contacts was recorded by means of the Dodge duplex signal magnet (see *B*, fig. 8).[a] This signal magnet has the unique advantage of recording three different events by one writing-point. In the case of typewriting, these three events can not possibly be confused. The general arrangement of this signal marker and its action is indicated in the diagram. There are two sets of electromagnets, *H* and *H′*, and *I* and *I′*. The latter magnet is below *I* in the figure and is not visible. There are two armatures, *J* and *K*. The latter carries a light aluminum rod, one end of which is the writing-point *S;* the other end forms a connection at *N* with the armature *J* and is kept in position by the spring *O*. Thus, when the circuit *E* on the typewriter is closed, actuating the magnet *H* and *H′*, the armature *J* causes the writing point *S* to deflect to the left, forming the tracing *T* on the kymograph drum. When contact *F* on the typewriter is closed, actuating the electro-magnet *I* and *I′*, the writing-point *S* is deflected to the right, forming the deflection *U* on the record. Since the space-bar closes both contacts *G* and *F*, the latter being connected with the escapement mechanism, both sets of electromagnets are actuated and both armatures move, with the resulting movement of the writing-point *S*, as indicated at *V* on the record. (See also fig. 9.)

The kymograph,[b] which is an electrically-driven instrument and quite accurate in its speed, carries a drum with a peripheral circumference of 500 mm. It is so arranged that the record may be taken in a spiral, with a pitch providing a separation of 2 mm. for the different lines of the record. By this arrangement it is possible, when running the kymograph at a rate of 100 mm. per second, to record on one sheet a performance requiring several minutes. Thus the record was sufficiently lengthened so that the time measurements could be made with more accuracy than was really necessary. Control records of the time intervals were consistently registered on the kymograph paper by signal magnet *D* in series, and operated by the 2-second pendulum of a large clock. The time record in no way confused that of the typewriting performance.

Portions of typewriting records as made on the kymograph are reproduced full size in figure 9. In the lower portion of the figure, which is from a typical record made during the repeated writing of the practice sentence "Now is the time for all brave men to come to the aid of their country," the first words of typewriting copy that are associated with the bottom line of this record are also given. From this it is seen that the indications on the record are perfectly legible so far as their association with strokes or spaces on the typewriter is concerned. From such a record the analysis of the time relation for the different acts can be made minutely, although it is recognized that in connection with each act we do not have what corresponds to a high-speed motion picture record. Before a particular key is struck there is an interval during which the process is becoming elaborated

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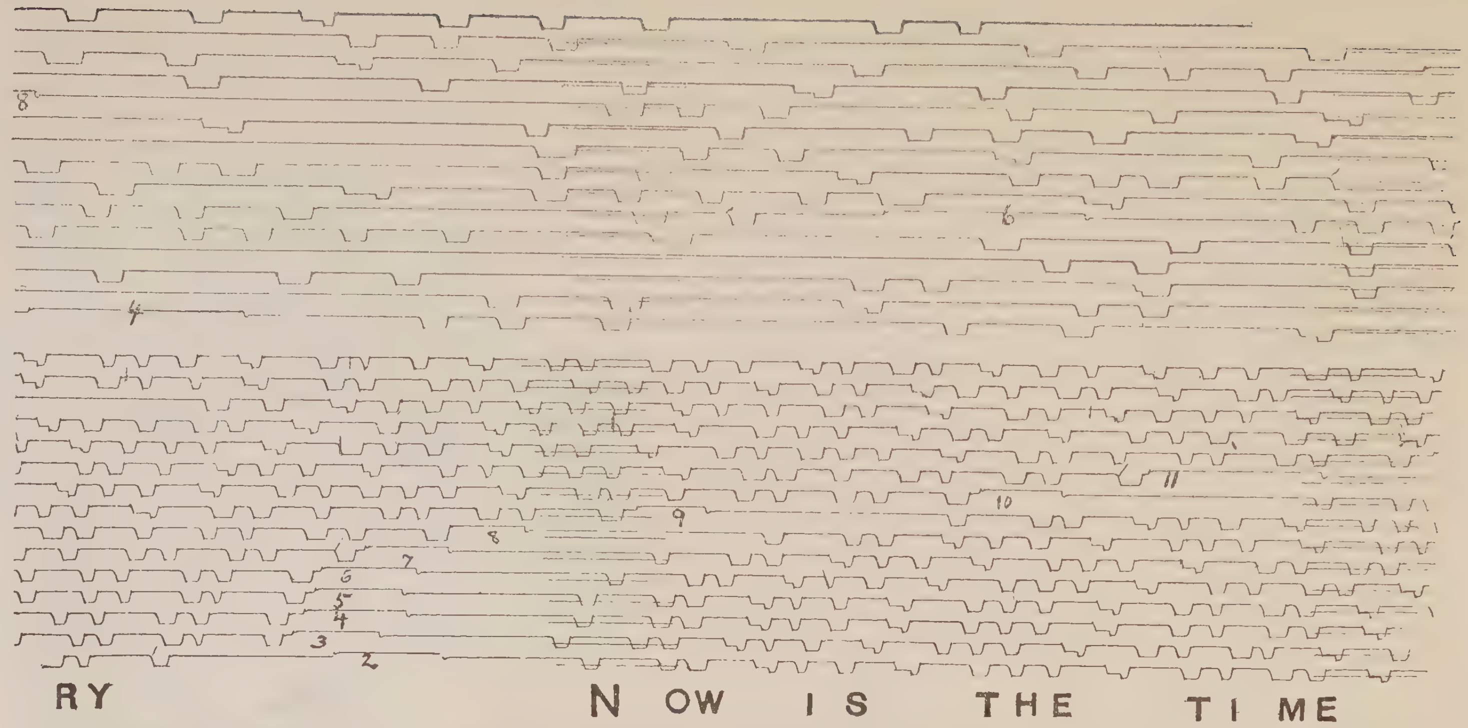
[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 192.

[b] Blix, Arch. f. d. ges. Physiol., 1902, 90, p. 405.



The lower section of the figure is from a typical record made during repeated writing of the practice sentence "Now is the time for all brave men to come to the aid of their country." The small digits 2, 3, 4, etc., indicate the operation of the carriage lever at the beginning of each sentence. At the right of 2 and beginning immediately below the parallel lines of the time record, the first part of the sentence has been printed, thus giving opportunity for direct comparison of the kymographic and typewritten records.

The upper section of the figure is from a typical record made by the same subject (*Fam*) when writing the nonsense 5-letter groups. The carriage action is indicated at 4, 6, and 8. For example, on the bottom line of this section to the right of 4 there are five notches for the individual letters and then a double notch for the space. Here the recording drum moved at the same rate as for the practice sentence. Note the prolonged pressure on the typewriter keys when writing the nonsense copy.

Fig. 9.—Portions of Two Sample Kymograph Records of Typewriting (Natural Size).

in the neuro-muscular system and before the appropriate muscle-group is brought into play, that is, before there is any movement whatever. Then there is a time when the finger is moving in the direction of the key which should be appropriately struck. Presently the key is found and a certain amount of pressure is exerted on it. The duration of time between letters, that is, when the signal magnets are not actuated, is shown on the record, thus representing the initiation and elaboration of the process. The time during which the letter is held down and the signal magnet deflected, represents the duration of pressure by the finger of the operator and also to some extent the lag in the mechanism in its return to the neutral position. It can not be assumed that each habit works separately and must complete itself up to the point of printing the letter and releasing the keys before the next habit begins to elaborate the neuro-muscular act which will be required for its proper fulfilment. A number of these habits are in process at the same time, and the more skilled the typist, possibly the larger is the number of such overlapping neuro-muscular events that are taking place at a given instant.

We have not undertaken to make as minute a study of these processes as the foregoing paragraph hints at. In fact, such a study, even in reference to the purely psychological phases of typewriting, remains to be made by those who are primarily interested in this skilled act and in the psychology of learning. Typewriting efficiency has often been measured on the gross basis of words per minute or of the number of strokes performed in a certain time period and the percentage number of errors. We have taken the line of typewriting as a unit, this containing one carriage movement and a number of strokes varying from 65 to 75. In each such unit the number of strokes per second and the number and percentage of errors have been determined.

Method of Counting Strokes and Errors in Typewriting.

In grading the typewritten sheets, an arbitrary method has been adopted by which one stroke has been counted for each letter, figure, or punctuation mark which did not require the use of a shift-key, one stroke for each operation of the shift-key, and but one-half stroke for each operation of the space-bar.[a] The operation of the shift-key requires a longer time than one of the letter keys. However, the capitalization of a letter requires about the same amount of time, since both hands are operating at once, as it does to strike two letters successively. Thus each capitalized letter is counted as two strokes. The appearance of other symbols in the copy which required the operation of a shift-key was very rare. Each typewriting task was begun with a preliminary carriage movement, so that for each line of typewriting one carriage movement has been included. From the kymograph record the time for each complete line of typewriting has been measured to 0.01 second; the total number of strokes in that particular line has then been divided by the time represented on the kymograph record, and the number of strokes per second thus secured.

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[a] Some other investigators of typewriting count the space-bar and key action on the same basis. It is unnecessary to give the references at hand or to discuss the matter here in detail. Our treatment has been uniform with all the data and for a comparison is therefore adequate.

The counting of the errors is a more difficult matter in elaborating the records than the determination of the number of strokes. For convenience, errors have been classified under four different heads:

(1) *Errors in striking letters, spaces, figures, or punctuation marks.*—One error has been counted for each of the following occurrences: omitting, inserting, repeating, substituting, illegibility due to too light a stroke, transposing, i. e., reversing the order of any two symbols, and causing two symbols to overlap.

(2) *Errors in capitalization.*—Each of the following is counted as one error: failure to capitalize a letter, unnecessary capitalization of a letter, and striking a letter or symbol seriously out of line when using the shift-key.

(3) *Errors involving whole words.*—The following have been considered as individual errors: omitting, inserting, repeating, substituting a word, or reversing the order.

(4) *Locking of keys.*—When the subject touched two keys so closely together that they locked, it has been counted an error. Occurrences of this kind had to be noted at the time and properly recorded, as they do not always show characteristically on the kymograph record.

An error has been classified under but one head, that is, counted but once unless it involved capitalization. After the number and percentage of errors have been determined for each complete line of typewriting, the average has been taken for all the lines of typewriting which made up the task, and the mean variation determined in each case. The writing was double spaced. Marginal stops have not been considered of importance, as the typewriting corresponded line for line with the copy. Paragraphing was likewise not considered in the writing of the practice sentence, or in the nonsense material, but only appeared in the prose copy, and even here to a slight extent, since the paragraphs were long and only one indenture was required. The margins at the top and bottom of the sheet were without value for our purpose in estimating the efficiency in typewriting.

EXPERIMENTAL RESULTS FOR FIVE TYPISTS.

Typewriting of Practice Sentence.

Each of the five subjects wrote 20 times continuously the sentence which he believed he could write with maximum accuracy and speed. *Accuracy was constantly placed foremost in our frequently repeated instructions to each man* and deserves first attention in any consideration of efficiency in typewriting. In discussing the results for the different typewriting tests, we will therefore present, first, the data for the effect of alcohol upon the accuracy of the typewriting, and second, the effect upon the speed of the typewriting. The reader will bear in mind that these experiments concern moderate amounts of alcohol, such amounts as have, in fact, been considered by many individuals to exert no observable influence upon neuromuscular performance. Since we are attempting to isolate the influence of such a factor, it is necessary to control the experiments in various ways so that they will afford the best possible opportunity for contrasting alcohol with normal performance. We are attempting to discover if 21 to 28 grams of ethyl alcohol, taken at one time, measurably influence the typewriting efficiency and other neuro-muscular functions of a practiced operator. The question then arises whether an amount of alcohol 50 per cent larger (32 to 42 grams of ethyl alcohol taken at one time) produces a larger effect in the same direction as the small dose. Furthermore, it is desired that some information should be obtained as to the temporal relationship of this effect if such exists. How rapidly does the effect develop? When has it reached its maximum? What is the nature of its decline and in what way is this related to later performance? There is the further question of whether alcohol affects all kinds of typewriting and all neuro-muscular performance to about an equal extent. As is outlined in previous pages, a variety of typewriting tasks and of neuro-muscular measurements has been provided to throw light on this point. These measurements have been so chosen and arranged that they could all be performed in approximately 30 minutes, one complete round of the tests being termed an experimental period.

Two procedures have been employed for contrasting the results after alcohol with what we may term normal, or control, results. The first of these methods is the use of non-alcohol days on which the subject was given a control dose imitating the alcohol dose as far as possible, but containing no alcohol. The second was to introduce a preliminary period of experiment before the control dose was given on normal days and also before the alcohol dose was given on alcohol days, so that the first period on each day was completed before the dose of liquid was taken. Both of these methods were used by Dodge and Benedict and also by Miles, and have been fully described by them.[a] The procedure has also been schematically outlined on page 4 of this monograph. (See fig. 1.) In reviewing tables and other presentation of data which will follow, it is necessary to bear this experimental arrangement in mind. So far as the writer knows, it is the most comprehensive method for bringing out the influence of any factor. Since it applies to all our data here recorded, it will be found to simplify rather than to complicate the presentation of the essential results.

Effect of Alcohol on Accuracy in the Most Simple Typing.

The major tables have a uniform arrangement of which table 2 may be taken as the typical form. In this table are presented the results for errors in practice-sentence writing for our group of five subjects. All of these men had two preliminary days of practice, one normal and one alcohol, the results of which are not included in the comparison for effect of alcohol. (See table 1, p. 33.) Following these practice days, each man had two normal days, also two alcohol days, on which doses A and B were taken, respectively. The results of these four days are compared to determine the effect of the alcohol. The table is arranged in the same order throughout from the top downward. At the left side, the subject, date, and the character of the experiments are entered. Under period 1 is given the average percentage number of errors per line which each man made in writing the practice sentence in the first period. Following period 1 and just prior to the beginning of period 2 the dose for the day was taken. This interval is indicated by parallel vertical lines. The dosage for both control and alcohol days has already been noted on page 35 and in table 1. Following the dose the series of measurements was repeated again and again, each repetition or experimental period requiring one-half hour. On the average, eight periods were completed, that is, seven repetitions after the dose. The number of periods actually completed by the different men varied some-

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 21; Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 29.

TABLE 2.—*Errors made in typewriting practice sentences.*

Subject, date, and type of experiment.	Per cent of errors at successive half-hour periods.							
	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
Control:								
Lig, Sept. 30	0.8	1.6	1.4	2.7	3.8	2.3	2.4	2.2
Oct. 3	0.5	1.5	1.4	0.9	1.9	3.2	3.6	2.6
Roj (II),[1] Oct. 5	1.9	4.7	3.1	3.1	3.5	3.1	4.7	4.6
Oct. 8	3.0	3.2	5.0	3.0	3.3	3.7	4.3	4.7
Suf, Nov. 4	1.2	0.5	1.0	0.4	0.7	0.3	0.4	[2]0.4
Nov. 7	1.3	0.2	0.1	0.5	0.4	0.8	1.4	1.4
Fam (II),[1] June 10	0.3	0.4	0.6	1.0	1.3	1.2	1.6	0.6
June 13	0.9	1.2	1.3	2.2	1.2	0.9	1.2	2.4
Mih (II),[1] June 22	1.8	1.7	1.1	1.9	1.9	1.6	2.0	2.0
June 25	1.3	0.3	0.6	0.7	1.1	0.9	0.7	0.5
Averages (A)...	1.30	1.53	1.56	1.64	1.91	1.80	2.23	2.14
Differences (D).	......	+0.23	+0.26	+0.34	+0.61	+0.50	+0.93	+0.84
Alcohol, dose A:								
Lig, Oct. 1	1.2	1.6	1.6	1.5	1.5	1.7	1.8	1.5
Roj (II),[1] Oct. 6	1.8	2.6	7.8	3.4	5.8	4.6	2.6	4.7
Suf, Nov. 5	0.4	1.5	0.8	0.3	1.4	1.1	0.2	1.5
Fam (II),[1] June 11	0.9	1.1	0.6	2.4	2.2	2.4	2.0	2.4
Mih (II),[1] June 23	2.2	1.4	3.7	1.6	2.0	2.5	1.8	1.0
Averages (A_1)...	1.30	1.64	2.90	1.84	2.58	2.46	1.68	2.22
Differences (D_1).	......	+0.34	+1.60	+0.54	+1.28	+1.16	+0.38	+0.92
Alcohol, dose B:								
Lig, Oct. 2	3.1	2.9	5.1	5.3	3.1	2.6	3.1	3.1
Roj (II),[1] Oct. 7	2.6	3.7	8.6	7.5	8.7	8.7	8.4	6.5
Suf, Nov. 6	0.3	0.7	3.8	1.5	0.7	1.5	1.2	1.9
Fam (II),[1] June 12	0.5	0.6	1.9	2.6	1.3	1.3	1.5	1.1
Mih (II),[1] June 24	2.0	1.0	3.2	1.8	2.5	1.0	1.7	0.4
Averages (A_2)...	1.70	1.78	4.52	3.74	3.26	3.02	3.18	2.60
Differences (D_2).	......	+0.08	+2.82	+2.04	+1.56	+1.32	+1.48	+0.90
Effect of alcohol, dose A:								
Differences for group (D_1-D)...............		+0.11	+ 1.34	+ 0.20	+ 0.67	+ 0.66	− 0.55	+ 0.08
Contrast for group (A_1-A).		+0.11	+ 1.34	+ 0.20	+ 0.67	+ 0.66	− 0.55	+ 0.08
Per cent from differences...		+8.5	+103.0	+ 15.4	+51.6	+50.8	−42.3	+ 6.2
Per cent from contrast.....		+7.2	+ 85.9	+ 12.2	+35.0	+36.6	−24.6	+ 3.7
Effect of alcohol, dose B:								
Differences for group (D_2-D)...............		− 0.15	+ 2.56	+ 2.70	+ 0.95	+ 0.82	+ 0.55	+ 0.06
Contrast for group (A_2-A).		+ 0.25	+ 2.96	+ 1.10	+ 1.35	+ 1.22	+ 0.95	+ 0.46
Per cent from differences...		−10.0	+170.6	+113.2	+63.4	+54.7	+36.7	+ 4.0
Per cent from contrast.....		+16.3	+189.5	+128.0	+70.7	+67.8	+42.5	+21.5

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[1] The experiments in the first series with **Roj**, **Fam**, and **Mih** are not included in this and the subsequent tables in this chapter, as the discussion in Chapter II refers only to experiments with like conditions. (See Chapter III, p. 96, for discussion of **Roj I**, **Fam I**, and **Mih I**.)

[2] **Suf** completed only 7 periods on this date, but the value obtained in the seventh period was used for the eighth period in this and subsequent tables for complete comparison with the other subjects.

what. With certain of them there were as many as 10 periods on some days, while one, *Suf* (on November 4) completed only 7 periods.[a] To facilitate uniformity of presentation in the averages for the group, we consider only the results of the first 8 periods, the records being complete for these, except as noted. The individual averages for each period in all the experiments are given in the table, both for the preliminary periods and for the periods after the dose. A general average (A, A_1, and A_2) has also been calculated for each period, and below are given the algebraical differences (D, D_1, and D_2) between the average preliminary value and each average period value after the dose.

The average for the preliminary measurements on the normal days (period 1) is 1.30 per cent of errors per line for the practice sentence. After the control dose, the errors for periods 2, 3, 4, etc., were always somewhat larger, that is, 1.53, 1.56, 1.64 per cent, and so on. The values on normal days, which represent 5 different men and 10 different days, are not constant from period to period, since throughout these 4 hours uncontrollable factors were exercising their influence. Especially we may suppose the factor of fatigue or ennui was constantly increasing; a rather consistent gradual increase in errors is apparent up to the seventh period, with only a slight increase in the eighth. The average for the preliminary on the alcohol days with dose A is 1.30 per cent, which corresponds exactly with that found for the normal day. This identity is of course a mere matter of chance. Following dose A, the errors for periods 2 to 8 are in order 1.64, 2.90, 1.84, 2.58, 2.46, 1.68, and 2.22 per cent.

Since we have two sets of normals, i. e., the preliminary values and the values of the control experiments, we may calculate the effect of alcohol in two ways, as has been done in this and in subsequent tables. The first we may designate as the "*difference method*," as the effect is found by deducting the average differences for the periods of the control experiments from the average differences for the corresponding periods of the alcohol experiments (D_1 or $D_2—D$). The percentage effect is computed by using as base the value obtained by averaging the two averages for the preliminary values of the control experiments (A) and the alcohol experiments (A_1 or A_2).

The second method of computation of the effect of alcohol may be designated as the "*contrast method*," as we contrast directly the averages for the corresponding periods of the control (A) and alcohol experiments (A_1 or A_2), deducting the period averages of the control experiments from the corresponding period averages of the alcohol experiment (A_1 or $A_2—A$), the result representing the effect of alcohol. The percentage effect is computed by using the average for the control period as the base.

In discussing the typewriting series the effect of alcohol is also frequently given according to what may be termed the "*combination method*," the result obtained by averaging the values computed by the "difference method" and the "contrast method."

As we have here the results of 7 periods after the control or alcohol dose, each of 30 minutes, the values represent the effect of alcohol during about

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[a] The value given in the seventh period for *Suf* on November 4 in the tables of this series has always been arbitrarily used for the eighth period value so that the data for all subjects might be the better averaged.

3½ hours. In discussing the results, comparison will frequently be made between the effect as shown in periods 2, 3, 4, and 5 (the first 2 hours after alcohol) and in periods 6, 7, and 8 (the subsequent 1½ hours).

Using, first, the contrast method for computing the effect of alcohol, from the values in table 2, we subtract 1.53 (the average percentage error for the control period 2) from 1.64 (the average percentage error for period 2 after dose A), and obtain 0.11. (See Effect of alcohol, dose A, contrast for group.) This, using 1.53 as the normal base, represents a percentage increase in error due to the alcohol of 7.2 per cent. (See Effect of alcohol, dose A, per cent from contrast.) In like manner for period 3, the normal average of 1.56 may be subtracted from the average for period 3 with dose A of 2.90, and the difference obtained would be 1.34. On the basis of 1.56 (the normal average), this represents an increase in error due to alcohol of 85.9 per cent. From this it is clearly seen that in period 3 after alcohol, the percentage number of errors is nearly twice that found in period 3 without alcohol.

The different subjects after dose A show wide variation in the average errors for period 3, these ranging from 0.6 to 7.8 per cent. *Roj* (II), who shows the latter value, has also a large number of errors in his normal work, that is, 3.1 and 5.0 per cent for his two control days. If the averages for the third period on the two normal days for each subject be compared with the individual averages for period 3 after dose A, it will be observed that, with the exception of *Fam* (II), they all show a larger number of errors after alcohol. *Fam* (II), who happens to be exceptional in this particular period, is in line with the others in periods 2, 4, 5, 6, etc. The comparison need not be carried on in detail between the other periods, periods 2 and 3 serving as illustrations.

Continuing the use of the contrast method, we find that the effect of alcohol (dose A) in periods 4, 5, and 6, respectively, is 12.2, 35.0 and 36.6 per cent. There is a reversal of direction in period 7 amounting to 24.6 per cent and then a slightly increased number of errors in period 8 amounting to 3.7 per cent. If we group together periods 2, 3, 4, and 5, which represent the 2 hours following the ingestion of the alcohol, the average increase in error during this time is 35.1 per cent, whereas the average increase during periods 6, 7, and 8, that is, from 2 to 3½ hours following the ingestion of alcohol, equals 5.2 per cent. It will simplify comparison to make such groupings of periods throughout this chapter.

In the foregoing comparison by the contrast method we have wholly neglected the preliminary period, that is, period 1. We may suppose that there is not only a variation in the working ability throughout the experimental day, but that different days vary from each other somewhat, the individual finding himself at different levels due to any one of a number of circumstances. The values obtained in the preliminary periods have no relationship whatever to the dose but are taken for the sole purpose of determining, if possible, the working-level or condition of the day. The preliminary period also takes account of the practice-level which the subject has reached in the particular test under investigation, and is the basis of the computation of the effect of alcohol by the difference method previously outlined. This has been the method used in former studies, and theoretically it seems to us the best means of making an impartial and rigid comparison.

The average preliminary values for the normal and alcohol (dose A) days in table 2 happen to be identical. Consequently, the comparison of the actual values in this section of the table must necessarily give the same result, whether it is made by contrast or from differences. Since the basis for computing the percentage effect by the difference method (the preliminary value) is smaller than those used to compute the percentage by the contrast method (the averages after the dose), the percentages of change calculated by the difference method will be larger than those obtained by the contrast method. The percentage effects of alcohol for periods 2 to 8, inclusive, in table 2, as computed by the difference method, are 8.5, 103.0, 15.4, 51.6, 50.8, −42.3, and 6.2 per cent, the total average for the 7 periods following alcohol being an increase of 27.6 per cent in errors. (See Effect of alcohol, dose A, per cent from differences.) The average for periods 2 to 5, inclusive, that is, for two hours following the ingestion of alcohol, is an increase of 44.6 per cent, while for periods 6 to 8, inclusive, the increase is 4.9 per cent. Probably an average between the two methods, i. e., the "combination method," is actually the more just representation of the complicated situation with which we are confronted in making such comparisons. Thus averaged, the effect of the alcohol for periods 2 to 5 would be an increase of 40 per cent in number of errors, while for periods 6 to 8 the increase is 5 per cent, indicating in general a marked diminution of the effect of alcohol 2 hours after ingestion.

The effect of dose B on the errors in typewriting the practice sentence can also be seen by reference to table 2. The percentage of errors in the periods following the dose are in each case larger than those following either dose A or the control dose. If we contrast the values obtained with dose B and with the control dose for periods 2 to 8, inclusive, we find the percentage of increase in errors which are ascribable to the effect of the alcohol to be as follows: 16.3, 189.5, 128.0, 70.7, 67.8, 42.5, and 21.5 for the successive periods following the dose. This gives a consistent picture of the time relation of the alcohol effect, i. e., a relatively slight effect in the first half-hour following the dose, the maximum effect showing in period 3, somewhat less in period 4, and then a diminution until the end of the experiment. The average percentage of errors found in the first period, for the dose B experiments (1.70) is somewhat larger than the preliminary average value for the control experiments, or for the experiments with dose A. Since this is the case, it tends to make the alcohol effect appear smaller when we employ the preliminary of the day for this computation than when the contrast method is used. Thus computed, the percentages of effect for the different periods would be as follows: −10.0, +170.6, +113.2, +63.4, +54.7, +36.7, and +4.0. The average for periods 2 to 5 by the method of differences is a percentage increase in errors of +84.3, and by the contrast method the average is +101.1. We may assume that the increase in errors associated with the taking of dose B and in the 2 hours succeeding the dose is therefore for the practice sentence writing somewhat above 90 per cent. For periods 6 to 8, inclusive, the average by the method of differences is +31.8, by the contrast method, +43.9. The average of both methods shows an increase of errors 2 to 3½ hours following the ingestion of dose B amounting to about 38 per cent.

Effect of Alcohol on Speed in the Most Simple Typing.

In typewriting the practice sentence the subjects on the average were able to execute somewhat more than 6 strokes per second, the number being counted on the arbitrary basis adopted (see p. 42), which only allows one-half stroke for each operation of the space-bar. In table 2, page 45, the average errors in the control experiments were seen to increase gradually from period to period. In table 3, which assembles the group data for the speed in writing the practice sentence, there is shown a slight increase in

Table 3.—*Speed in typewriting practice sentences.*

Subject, date, and type of experiment.	Strokes per second at successive half-hour periods.							
	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
ntrol:								
Lig, Sept. 30	5.63	5.75	5.44	5.63	5.68	5.42	5.37	5.20
Oct. 3	5.45	5.23	5.49	5.80	6.12	6.01	5.48	5.61
Roj (II), Oct. 5	6.15	6.07	5.92	6.17	5.78	6.39	6.24	6.08
Oct. 8	6.75	6.82	6.63	6.49	6.52	6.27	6.65	6.07
Suf, Nov. 4	5.95	6.22	6.08	6.17	6.11	6.30	6.17	6.17
Nov. 7	6.22	6.27	6.49	6.43	6.56	6.42	6.70	6.55
Fam (II), June 10	5.75	6.21	6.21	6.02	6.10	5.76	5.98	6.30
June 13	6.29	6.38	6.32	6.38	6.61	6.40	6.77	6.59
Mih (II), June 22	6.47	6.60	6.79	6.63	6.32	6.49	6.25	6.20
June 25	6.14	6.72	6.64	6.63	6.58	6.47	6.41	6.44
Averages (A)	6.08	6.23	6.20	6.24	6.24	6.19	6.20	6.12
Differences (D)	......	+0.15	+0.12	+0.16	+0.16	+0.11	+0.12	+0.04
ohol, dose A:								
Lig, Oct. 1	5.37	5.52	5.73	5.53	5.19	5.56	5.48	5.59
Roj (II), Oct. 6	6.15	6.45	5.99	6.16	5.72	6.29	5.76	6.15
Suf, Nov. 5	5.90	5.86	6.47	6.29	6.16	6.23	6.34	6.23
Fam (II) June 11	6.32	6.50	6.38	6.45	6.21	6.30	6.52	6.14
Mih (II), June 23	6.22	6.52	5.86	6.02	6.04	6.19	6.26	6.23
Averages (A_1)	5.99	6.17	6.09	6.09	5.86	6.11	6.07	6.07
Differences (D_1)	......	+0.18	+0.10	+0.10	−0.13	+0.12	+0.08	+0.08
ohol, dose B:								
Lig, Oct. 2	5.36	5.58	5.24	5.38	5.27	5.65	5.26	5.53
Roj (II), Oct. 7	5.88	6.25	5.90	5.75	6.03	6.06	5.94	5.88
Suf, Nov. 6	6.09	6.22	6.28	6.36	6.45	6.18	6.31	6.23
Fam (II), June 12	6.05	6.54	6.40	6.27	6.57	6.68	6.42	6.75
Mih (II), June 24	6.37	6.53	5.97	6.08	6.06	6.29	6.07	6.37
Averages (A_2)	5.95	6.22	5.96	5.97	6.08	6.17	6.00	6.15
Differences (D_2)	......	+0.27	+0.01	+0.02	+0.13	+0.22	+0.05	+0.20
ct of alcohol, dose A:								
Differences for group (D_1-D)	......	+0.03	−0.02	−0.06	−0.29	+0.01	−0.04	+0.04
Contrast for group (A_1-A)	......	−0.06	−0.11	−0.15	−0.38	−0.08	−0.13	−0.05
Per cent from differences	......	+0.5	−0.3	−1.0	−4.8	+0.2	−0.7	+0.7
Per cent from contrast	......	−1.0	−1.8	−2.4	−6.1	−1.3	−2.1	−0.8
ct of alcohol, dose B:								
Differences for group (D_2-D)	......	+0.12	−0.11	−0.14	−0.03	+0.11	−0.07	+0.16
Contrast for group (A_2-A)	......	−0.01	−0.24	−0.27	−0.16	−0.02	−0.20	+0.03
Per cent from differences	......	+2.0	−1.8	−2.3	−0.5	+1.8	−1.2	+2.7
Per cent from contrast	......	−0.2	−3.9	−4.3	−2.6	−0.3	−3.2	+0.5

strokes per second between periods 1 and 2, i. e., from 6.08 to 6.23. From this figure it changes less than 1 per cent throughout periods 3 to 7, inclusive, and in period 8 it drops to only 6.12, which is slightly faster than the speed in period 1, and about 1.5 per cent slower than that in periods 2 to 7. From these values it may be judged that, in general, the performance of the group of typists was quite constant from period to period throughout the control experiments.

For the group of days when dose A was taken, it is again seen that the speed in period 1 is not so great as that in periods 2, 3 and 4. The speed in periods 6, 7, and 8 is also slightly faster than in period 1, but in period 5 is somewhat slower. The second period, which is relatively free from the effect of the alcohol, since it followed within 10 minutes of the ingestion of the liquid, shows in general the fastest speed for any period in the group of days, i. e., 6.17 strokes per second. From this point there is a gradual slowing up, the minimum speed appearing in period 5, after which there is a small but regular recovery. Comparing the results with dose A with those following the control solution by using the difference method, we find the percentage alcohol effect to be +0.5, −0.3, −1.0, −4.8, +0.2, −0.7, and +0.7, with an average of −0.8, for periods 2 to 8, respectively. By the contrast method, the effect in periods 2 to 8, inclusive, is as follows: −1.0, −1.8, −2.4, −6.1, −1.3, −2.1, and −0.8, with an average of −2.2 per cent. The average alcohol effect for periods 2 to 5, judged by the combination method, is −2.1 per cent, while for periods 6 to 8 it is −0.7 per cent.

When dose B was taken, the subjects averaged the following number of strokes per second for periods 1 to 8, inclusive: 5.95, 6.22, 5.96, 5.97, 6.08, 6.17, 6.00, and 6.15. The extreme range of difference between the first period and the others is only 0.27, this difference appearing between periods 1 and 2. Even in periods 3 and 4, when we might judge that the effect of the alcohol would be at its height, the subjects were able to write as rapidly on the average as they did in period 1. Here again the effect of alcohol on the speed of typewriting is only slight. According to the difference method, the maximum effect appears in periods 3 and 4, which are in order −1.8 and −2.3 per cent. By the contrast method, the effect is somewhat larger for periods 3 to 5, being −3.9, −4.3, and −2.6 per cent, respectively. Combining the two methods of computing the effect, we find the average results for periods 2 to 5 to be a decrease in speed of less than 2 per cent and in periods 6 to 8, a decrease of less than 0.5 per cent.

Typewriting Scientific Prose.

A skilled typist in successive periods of writing varies more in the accuracy than in the speed of work. In the nature of the case, it is seldom that the number of strokes per second would be changed as much as 100 per cent between two periods of typewriting, whereas the number of errors in one period may easily be double or treble the number made in another period. The percentage increase in errors represents a different category from the change in strokes per second. It is somewhat the same as the difference between the amplitude and the latency of reflexes when these two factors are measured separately in any curve representing reflex response. We are prepared, therefore, to find a rather greater variation between comparable preliminary periods in errors than in strokes per second.

EFFECT OF ALCOHOL ON ACCURACY IN COPYING PROSE.

In table 4, which shows the percentage of errors made by the group of typists in writing prose copy, the averages for preliminary periods on the control days and on the groups of alcohol days are 2.19, 1.66, and 2.34 per cent. This is a considerable difference and may not be ascribed to any one

TABLE 4.—*Errors made in typewriting scientific prose copy.*

bject, date, and type of experiment.	Per cent of errors at successive half-hour periods.							
	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
ntrol:								
Lig, Sept. 30	2.9	2.5	2.4	3.7	2.4	3.7	2.5	3.2
Oct. 3	2.0	1.9	2.4	2.2	3.2	3.9	3.9	2.3
Roj (II), Oct. 5	2.2	1.9	2.9	3.3	2.8	3.3	1.8	2.3
Oct. 8	3.2	1.6	1.9	3.2	2.2	3.6	2.2	2.7
Suf, Nov. 4	3.0	1.7	1.6	1.5	1.2	2.7	1.4	1.4
Nov. 7	2.0	1.8	2.3	2.1	2.4	1.5	2.7	2.7
Fam (II), June 10	1.3	2.1	1.5	1.9	1.8	1.7	2.3	2.0
June 13	2.7	1.5	2.1	2.0	2.1	2.2	1.8	2.3
Mih (II), June 22	1.6	1.6	1.1	1.5	1.3	0.8	1.3	1.1
June 25	1.0	0.8	0.8	1.1	1.1	1.0	0.8	0.6
Averages (A)	2.19	1.74	1.90	2.25	2.05	2.44	2.07	2.06
Differences (D)	......	−0.45	−0.29	+0.06	−0.14	+0.25	−0.12	−0.13
ohol, dose A:								
Lig, Oct. 1	2.0	1.6	3.0	4.0	3.1	3.2	3.1	3.3
Roj (II), Oct. 6	1.2	2.5	3.4	5.8	2.9	4.8	3.3	2.3
Suf, Nov. 5	2.7	2.4	2.7	2.4	1.0	2.6	2.3	2.3
Fam (II), June 11	1.7	2.0	2.3	3.8	3.1	2.4	2.2	2.6
Mih (II), June 23	0.7	2.1	2.7	3.1	1.8	1.5	1.2	1.2
Averages (A_1)	1.66	2.12	2.82	3.82	2.38	2.90	2.42	2.34
Differences (D_1)	......	+0.46	+1.16	+2.16	+0.72	+1.24	+0.76	+0.68
ohol, dose B:								
Lig, Oct. 2	3.4	3.6	3.4	4.5	3.9	4.6	3.2	3.6
Roj (II), Oct. 7	2.0	2.0	3.7	5.4	5.9	5.6	4.2	5.0
Suf, Nov. 6	2.9	1.7	4.0	3.7	2.0	2.7	2.5	2.3
Fam (II), June 12	1.9	1.8	2.3	2.0	1.9	2.5	2.3	2.4
Mih (II), June 24	1.5	3.1	3.2	3.0	2.1	2.5	1.7	1.5
Averages (A_2)	2.34	2.44	3.32	3.72	3.16	3.58	2.78	2.96
Differences (D_2)	......	+0.10	+0.98	+1.38	+0.82	+1.24	+0.44	+0.62
ct of alcohol, dose A:								
Differences for group (D_1-D)	......	+ 0.91	+ 1.45	+ 2.10	+ 0.86	+ 0.99	+ 0.88	+ 0.81
Contrast for group (A_1-A)	......	+ 0.38	+ 0.92	+ 1.57	+ 0.33	+ 0.46	+ 0.35	+ 0.28
Per cent from differences	......	+47.2	+75.2	+108.8	+44.6	+51.3	+45.6	+42.0
Per cent from contrast	......	+21.8	+48.4	+ 69.8	+16.1	+18.8	+16.9	+13.6
t of alcohol, dose B:								
Differences for group (D_2-D)	......	+ 0.55	+ 1.27	+ 1.32	+ 0.96	+ 0.99	+ 0.56	+ 0.75
Contrast for group (A_2-A)	......	+ 0.70	+ 1.42	+ 1.47	+ 1.11	+ 1.14	+ 0.71	+ 0.90
Per cent from differences	......	+24.2	+56.0	+ 58.2	+42.3	+43.6	+24.7	+33.1
Per cent from contrast	......	+40.2	+74.8	+ 65.3	+54.2	+46.7	+34.3	+43.6

or two subjects. The extreme range between the averages for the various periods of the normal days is from 1.74 for period 2 to 2.44 per cent for period 6. There is no regularly characteristic change which seems to take place during the whole session. The preliminary for the experiment made with dose A shows only a small percentage error, i. e., 1.66 per cent, this being somewhat less than that found in any other period in table 4. Consequently, when the effects of alcohol are computed by the difference method, the small value for the preliminary period makes this effect seem large. The percentages from differences for the various periods following dose A on this basis are +47.2, +75.2, +108.8, +44.6, +51.3, +45.6, and +42.0, with an average of +59.3 per cent.

The most legitimate way for us to correct for the fact that period 1 with dose A is low and thus makes the alcohol effect high is also to compute the effect by the contrast method. Although there are some irregularities, still the percentage of errors made following the dose of alcohol is always greater, period for period, than the percentage of errors following the control dose. We have for period 2, dose A, 2.12, as compared to 1.74 per cent following the control dose. By this method of direct contrast, the alcohol days show increases of errors due to dose A amounting to +21.8, +48.4 +69.8, +16.1, +18.8, +16.9, and +13.6 per cent, with an average of +29.3 per cent, as compared with +59.3 per cent when computed the other way. There is considerable probability that the direct comparison in this case is a more just expression for the results, but the combination method may also be used by averaging the results for the two methods. These averages for the effect of alcohol are therefore +54.0 per cent for periods 2 to 5, and +31.4 per cent for periods 6 to 8.

In the case of dose B, the normal performance gives 2.34 per cent of error, which is somewhat above the results for the normal days, just as in the case of dose A we have seen that the value for period 1 is somewhat below. The discrepancy with dose B is not so great as that with dose A, but this increase in basal level will tend to make the effect of dose B appear smaller, just as the use of the preliminary value made the effect of dose A appear larger. With dose B, however, all of the periods following the alcohol dose give higher percentages of error than were found in the preliminary periods. On the normal days, on the contrary, most of the periods following the control dose show results which have a less percentage of error than in the preliminary period. By the difference method, the effect of dose B for periods 2 to 8, inclusive, is found to be +24.2, +56.0, +58.2, +42.3, +43.6, +24.7, and +33.1, with an average of +40.3 per cent. When the alcohol performance following dose B is contrasted directly, period for period, with the normal performance following the control dose, we have percentages for the effect of alcohol as follows: +40.2, +74.8, +65.3, +54.2, +46.7, +34.3, and +43.6, with an average of +51.3 per cent. As an average of the 2 hours following the ingestion of alcohol, i. e., periods 2 to 5, the combination method shows increases in errors amounting to 51.9 per cent and for periods 6 to 8, inclusive, which cover 2 to 3½ hours following ingestion, the average increase in error is 37.7 per cent. By this method of presentation, the effect of alcohol appears to be as great with dose A as with dose B and, in fact, a little stronger in periods 2 to 5. There is reason to think that this is an artifact. Probably the actual condition would be better shown by simply using the method of direct comparison, by which the average effect for dose A in periods 2 to 5 is +39.0 per cent, while that for dose B in the corresponding periods is +58.6 per cent. A similar comparison for periods 6 to 8 gives +16.4, and +41.5 per cent; therefore, in the first 2 hours, dose B, which was one and one-half times as large as the other (A), produced an effect 1½ times greater than dose A, and this difference is somewhat larger proportionately in the last three periods of the day.

Effect of Alcohol on Speed in Copying Prose.

Judged from the standpoint of speed, the prose copy was about 17 per cent harder than the practice sentence work. When the practice sentence was written over and over, the average subject wrote about 6 strokes per second, while in copying the paragraphs of scientific prose, the average number of strokes was about 5 per second. (See table 5.) The preliminary period for normal days gave an average of 5.02 strokes per second. For succeeding periods on this same group of days, the value remains quite constantly about 5 strokes, the widest diversion from this being in period 6, in which the speed is 4.75 strokes. The individual scores which make up this latter average are in every case smaller than the scores for the same subjects in period 5. The scores are also smaller than those in the succeeding period (No. 7), the only exception being *Suf,* on November 7. When we take into consideration the fact that in period 6 on normal days the average number of errors was greater than in period 5 or period 7 (see table 4), it seems probable that the copy for period 6 must have been more difficult. According to our experimental routine, the same copy was used in the same position in the two series of experiments with alcohol. Accordingly, if the copy for period 6 was more difficult on the normal days, this would likewise be apparent on the alcohol days. Incidentally, we may note that the number of strokes per second in period 6 after both dose A and dose B is less than the number in either period 5 or period 7. It is unfortunate that there should have been this inequality in the copy. Such difficulties, it seems, only come to light after considerable experimentation with the material.

The average strokes per second in the preliminary period before dose A and dose B are within 1 per cent of the preliminary average for the normal days; consequently the alcohol effect upon the number of strokes per second figured in both ways will be approximately the same. By the difference method there is an average alcohol effect for all periods for dose A of −2.6 per cent in strokes per second. In periods 3, 4, and 5, the average effect is −5.3, −4.0, and −4.4. In the other periods, the values are smaller and less consistent. If the effect of dose A is computed by direct contrast, the average effect in periods 2 to 8 is −1.4 per cent. For the 2 hours following alcohol (periods 2 to 5), the difference method shows an average effect of −3.7 per cent, and the contrast method −2.5 per cent; the average for these results is −3.1 per cent. In a like comparison for periods 6 to 8, the two methods give −1.3 per cent and ±0 per cent, respectively, from which we may assume that there was no definite change. The difficulty in these periods seems to rise especially out of the results for period 6 which were previously discussed.

The effect of dose B on the speed of copying scientific prose is little, if any, more striking than that found with dose A. By the difference method, the results for periods 2 to 8, inclusive, are −1.8, −5.4, −3.6, −4.2, +0.4, ±0.0, +1.6, with an average of −1.9 per cent for all periods. By the direct contrast method, the average effects for the same periods in order from 2 to 8 are −2.0, −5.5, −3.8, −4.3, +0.2, −0.2, and +1.4, with an average of 2.0 per cent. By both methods of computation there is a fairly definite effect in periods 3, 4, and 5, which ranges from about 3 to 6 per cent and is most pronounced in period 3. The difference method gives an average effect in periods 2 to 5 of −3.8 per cent, while by the contrast method the

TABLE 5.—*Speed in typewriting scientific prose copy.*

Subject, date, and type of experiment.	Strokes per second at successive half-hour periods.							
	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
Control:								
Lig, Sept. 30	4.48	4.56	4.60	4.46	4.55	4.22	4.52	4.44
Oct. 3	4.47	4.72	4.89	4.82	4.74	4.64	4.94	4.71
Roj (II), Oct. 5	5.41	5.33	5.25	5.06	5.09	4.84	5.16	5.13
Oct. 8	5.70	5.69	5.52	5.23	5.52	4.85	5.09	5.00
Suf, Nov. 4	4.03	4.08	4.11	3.85	4.14	3.77	4.15	4.15
Nov. 7	4.18	4.28	4.02	4.20	4.39	4.23	4.16	4.03
Fam (II), June 10	5.08	5.32	5.23	5.22	5.43	4.80	5.51	5.61
June 13	5.65	5.57	5.55	5.35	6.01	5.44	5.65	5.74
Mih (II), June 22	5.61	5.74	5.79	5.73	5.75	5.52	5.74	5.19
June 25	5.59	5.55	5.70	5.52	5.53	5.21	5.44	5.14
Averages (A)	5.02	5.08	5.07	4.94	5.12	4.75	5.04	4.91
Differences (D)	......	+0.06	+0.05	−0.08	+0.10	−0.27	+0.02	−0.11
Alcohol, dose A:								
Lig, Oct. 1	4.40	4.76	4.52	4.54	4.58	4.50	4.50	4.42
Roj (II), Oct. 6	5.42	5.51	5.34	4.86	4.92	4.70	5.00	5.02
Suf, Nov. 5	4.27	4.26	4.04	4.16	4.43	4.04	4.13	3.98
Fam (II), June 11	5.63	5.52	5.50	5.66	5.70	5.55	5.75	5.73
Mih (II), June 23	5.67	5.40	4.91	4.77	5.15	5.28	5.45	5.41
Averages (A_1)	5.08	5.09	4.86	4.80	4.96	4.81	4.97	4.91
Differences (D_1)	......	+0.01	−0.22	−0.28	−0.12	−0.27	−0.11	−0.17
Alcohol, dose B:								
Lig, Oct. 2	4.42	4.39	4.41	4.39	4.48	4.42	4.63	4.41
Roj (II), Oct. 7	5.34	5.38	5.34	4.89	5.09	5.03	5.24	5.17
Suf, Nov. 6	4.17	4.33	3.84	4.03	4.16	3.96	4.28	4.16
Fam (II), June 12	5.40	5.32	5.54	5.55	5.51	5.31	5.72	5.86
Mih (II), June 24	5.72	5.49	4.83	4.87	5.28	5.09	5.27	5.29
Averages (A_2)	5.01	4.98	4.79	4.75	4.90	4.76	5.03	4.98
Differences (D_2)	......	−0.03	−0.22	−0.26	−0.11	−0.25	+0.02	−0.03
Effect of alcohol, dose A:								
Differences for group ($D_1 - D$)	......	−0.05	−0.27	−0.20	−0.22	±0.00	−0.13	−0.06
Contrast for group ($A_1 - A$)	......	+0.01	−0.21	−0.14	−0.16	+0.06	−0.07	±0.00
Per cent from differences	......	−1.0	−5.3	−4.0	−4.4	±0.0	−2.6	−1.2
Per cent from contrast	......	+0.2	−4.1	−2.8	−3.1	+1.3	−1.4	±0.0
Effect of alcohol, dose B:								
Differences for group ($D_2 - D$)	......	−0.09	−0.27	−0.18	−0.21	+0.02	±0.00	+0.08
Contrast for group ($A_2 - A$)	......	−0.10	−0.28	−0.19	−0.22	+0.01	−0.01	+0.07
Per cent from differences	......	−1.8	−5.4	−3.6	−4.2	+0.4	±0.0	+1.6
Per cent from contrast	......	−2.0	−5.5	−3.8	−4.3	+0.2	−0.2	+1.4

effect is −3.9 per cent. In periods 6 to 8, the effect is in the opposite direction. By the difference method, it is +0.7 per cent, and by the contrast method, +0.5 per cent.

TYPEWRITING NONSENSE MATERIAL.

EFFECT OF ALCOHOL ON ACCURACY IN THE MOST DIFFICULT TYPING.

The three classes of material which made up the three parts of the typewriting experiment—practice sentence, prose copy, and nonsense copy—characteristically show three levels of error. The average percentage of errors normally made by our typists in writing the practice sentence was about 1.5 for every 100 strokes; with the prose copy it was approximately 2.0 per cent; in the nonsense material it was about 3.0 per cent. Such writing of groups of unrelated letters as was demanded in the nonsense copy is a very trying task, as well as a slow one, since the usual typewriting word and phrase habits are not allowed to function, so that the whole operation is carried on at practically the greatest disadvantage. The results are given in table 6.

The averages for percentage of errors in the 8 periods on the 10 normal days are fairly uniform from period 1 to period 6, inclusive, the widest range being from 2.86 to 3.16, approximately a 10 per cent range. During the last two periods, i. e., seventh and eighth, the percentage of errors increases to 3.68 and 3.84, respectively. The average preliminary value for period 1 for the five days with dose A is 3.08 per cent, which is almost identical with the preliminary value for the normal days, hence the two methods of computing the percentage effect of alcohol will give practically the same results for dose A. By the difference method, the alcohol effect with dose A for periods 2 to 8, respectively, is +31.4, +36.9, +8.4, +18.8, +34.7, −17.8, and +4.2, with an average for all periods of +16.7 per cent. If the alcohol effect is computed by directly contrasting the two sets of values without regard to period 1, we have percentage increases in error of +33.5, +36.8, +8.4, +18.3, +33.5, −15.2, and +3.1 per cent, with an average of +16.9 per cent. Period 7 seems curiously out of line so far as its sign is concerned, also period 4 as to the amount of effect at this point, the value shown being considerably smaller than those for periods 3 and 5. By the difference method the average for periods 2 to 5 is +23.9 per cent, and by direct contrast +24.3 per cent, which is close agreement at 24 per cent for the effect during the two hours following ingestion. For periods 6 to 8 the differences show +7.0 per cent, while the contrast method gives +7.1 per cent, a further agreement which needs no comment.

For dose B the preliminary first period value is considerably different from that for either dose A or the normal days, i. e., 2.20 per cent as against 3.08 per cent. There is no explanation at hand for this lower percentage of error. It will be observed that *Fam* II, June 12, in the first period, has a score of 0.2 per cent for error. This is the smallest score that he or anyone else made in this test for nonsense writing, and as there are only five entries in each column of the dose B values, this naturally tends to reduce the average. With so small a preliminary value as we have here, the effect of the alcohol is prominent. For periods 2 to 8 in order, the percentages of increase in error by differences are +123.0, +84.2, +103.8, +59.9, +45.9,

+46.6, and +53.4, with an average for all periods of +73.8 per cent. In general, the values for the periods covering the first 2 hours after ingestion

TABLE 6.—*Errors made in typewriting 5-letter nonsense combinations.*

Subject, date, and type of experiment.	Per cent of errors at successive half-hour periods.							
	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
Control:								
Lig, Sept. 30..	2.5	2.9	4.4	4.4	4.1	4.8	3.9	5.4
Oct. 3..	3.0	2.3	2.5	3.7	1.8	2.7	4.0	3.1
Roj (II), Oct. 5..	2.8	3.0	4.6	3.2	4.1	3.0	4.6	5.0
Oct. 8..	6.0	4.1	4.5	3.6	4.8	3.6	4.4	5.9
Suf, Nov. 4..	3.9	4.1	3.1	4.2	4.9	4.1	5.4	5.4
Nov. 7..	4.4	3.5	4.1	4.7	4.8	5.4	5.1	4.4
Fam (II), June 10..	2.8	1.6	1.8	0.9	1.6	1.4	3.3	3.7
June 13..	2.3	4.1	2.7	3.1	2.0	3.7	3.4	3.0
Mih (II), June 22..	1.8	1.6	2.5	1.4	1.6	1.8	1.6	1.1
June 25..	1.4	1.4	0.5	0.7	1.4	1.1	1.1	1.4
Averages (A)....	3.09	2.86	3.07	2.99	3.11	3.16	3.68	3.84
Differences (D)..	......	−0.23	−0.02	−0.10	+0.02	+0.07	+0.59	+0.75
Alcohol, dose A:								
Lig, Oct. 1..	2.8	3.2	3.4	3.9	5.5	5.1	2.5	3.2
Roj (II), Oct. 6..	2.9	4.3	5.9	4.8	3.7	4.8	5.5	6.2
Suf, Nov. 5..	4.1	6.2	3.7	4.5	4.6	6.3	3.9	5.1
Fam (II), June 11..	2.5	2.7	3.9	2.1	2.5	3.1	1.4	2.1
Mih (II), June 23..	3.1	2.7	4.1	0.9	2.1	1.8	2.3	3.2
Averages (A_1) ...	3.08	3.82	4.20	3.24	3.68	4.22	3.12	3.96
Differences (D_1)..	......	+0.74	+1.12	+0.16	+0.60	+1.14	+0.04	+0.88
Alcohol, dose B:								
Lig, Oct. 2..	3.7	6.5	5.5	3.9	6.5	3.5	2.5	3.9
Roj (II), Oct. 7..	2.5	3.9	5.7	6.8	4.8	7.1	7.6	5.5
Suf, Nov. 6..	3.2	6.7	5.3	7.2	3.0	3.4	5.7	6.2
Fam (II), June 12..	0.2	1.4	1.8	2.7	3.1	1.3	2.5	3.2
Mih (II), June 24..	1.4	7.6	3.7	3.6	1.6	2.1	1.8	3.0
Averages (A_2)....	2.20	5.22	4.40	4.84	3.80	3.48	4.02	4.36
Differences (D_2)..	......	+3.02	+2.20	+2.64	+1.60	+1.28	+1.82	+2.16
Effect of alcohol, dose A:								
Differences for group (D_1-D)...	......	+ 0.97	+ 1.14	+0.26	+ 0.58	+ 1.07	− 0.55	+0.13
Contrast for group (A_1-A).........	......	+ 0.96	+ 1.13	+ 0.25	+ 0.57	+ 1.06	− 0.56	+0.12
Per cent from differences.........	......	+ 31.4	+36.9	+ 8.4	+18.8	+34.7	−17.8	+4.2
Per cent from contrast...........	......	+ 33.5	+36.8	+ 8.4	+18.3	+33.5	−15.2	+3.1
Effect of alcohol, dose B:								
Differences for group (D_2-D)...	......	+ 3.25	+ 2.22	+ 2.74	+ 1.58	+ 1.21	+ 1.23	+ 1.41
Contrast for group (A_2-A).........	......	+ 2.36	+ 1.33	+ 1.85	+ 0.69	+ 0.32	+ 0.34	+ 0.52
Per cent from differences.........	......	+123.0	+ 84.2	+103.8	+59.9	+45.9	+46.6	+53.4
Per cent from contrast...........	......	+ 82.5	+ 43.3	+ 61.9	+22.2	+10.1	+ 9.2	+13.5

are the larger, as we have almost uniformly thus far noted. If we disregard period 1 and directly contrast those which follow with the normal values, the effects are in order +82.5, +43.3, +61.9, +22.2, +10.1, +9.2, and +13.5 per cent, with an average of +34.7 per cent. The average effect for the two hours following alcohol by the method of differences is an increase in error amounting to +92.7 per cent; by the method of contrast, +52.5 per cent. There is thus a considerable discrepancy between the results obtained by the two methods of computation. In this case the latter is probably the more trustworthy, but we may as heretofore combine the two, and obtain an average effect of +72.6 per cent. Similarly, the results for periods 6 to 8 by the difference and contrast methods are +48.6 and +10.9 per cent, respectively, the average being +29.7 per cent. The effect of dose B on the percentage of error is more than the proportional difference in the size of the alcohol content of the two doses.

Effect of Alcohol on Speed in the Most Difficult Typing.

The differences normally occurring with the three types of copy are pronounced when the speed of typewriting is compared. From table 7, it appears that the average normal performance with the nonsense copy was about 2.5 strokes per second. This is just half the rate which was common in writing the scientific prose. The average preliminary values for all three groups of days are practically the same, ranging from 2.54 before dose A to 2.69 before dose B, with the normal group of 10 days averaging 2.60 strokes per second. Following the control dose there was not much change in the rate of typewriting until about the sixth period, when the speed decreased slightly. By the difference method, dose A produced a slightly slower speed in periods 2 to 5, while beyond that point the results were apparently in the opposite direction. The alcohol values when compared directly with the normal values period for period, give somewhat larger effects. For the periods 2 to 8, they were in order as follows: −2.8, −4.8, −4.4, −2.8, ±0.0, −0.4, and −1.3, with an average of −2.4 per cent. The difference method gives an average effect of −1.3 per cent for periods 2 to 5, inclusive, as against −3.7 per cent for the contrast method. The combined average for these four periods is −2.5 per cent. For the interval represented by periods 6 to 8, the results are opposed, the difference method giving +1.8 per cent, while the contrast method shows −0.6 per cent. The average would thus be less than 1 per cent in the plus direction.

The larger amount of alcohol, dose B, produced a somewhat larger effect, especially in periods 2 and 3. By the method of differences, the percentage effect for the periods in order are −11.7, −9.1, −5.3, −5.3, −2.3, −4.5, and −0.4, with an average of −5.5 per cent in the speed of writing the nonsense copy. These values are all in one direction and somewhat large, owing to the fact that the performance in the first period on dose B days was highest in average speed of any period included in table 7. When the periods following alcohol are contrasted directly with those following the control dose, the alcohol effect is −8.7, −6.0, −2.0, −2.0, +1.3, −1.2, and +3.4, with an average of −2.2 per cent. Hence, while the differences demonstrate an alcohol effect of −7.9 for the 2 hours following ingestion (periods 2 to 5), the effect according to the contrast method is −4.7 per cent; the average would therefore be a general decrease in speed of 6.3 per cent. This is the largest change in speed of typewriting in the 2-hour period which we have found in connection with any of the typewriting tasks. In the period from 2 to 3½ hours after the alcohol (periods 6 to 8), the difference method gives an effect of −2.4 per cent, while the contrast method reverses the direction, that is, the average is +1.2 per cent. Since the average result by these two methods is −0.6 per cent, we must conclude that there was no certain change in speed of typewriting attributable to the alcohol at this period in the experimental session.

Table 7.—*Speed in typewriting 5-letter nonsense combinations.*

Subject, date, and type of experiment.	Strokes per second at successive half-hour periods.							
	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
Control:								
Lig, Sept. 30	2.54	2.48	2.46	2.54	2.55	2.47	2.47	2.41
Oct. 3	2.72	2.66	2.65	2.70	2.80	2.63	2.58	2.44
Roj (II), Oct. 5	2.92	2.95	2.75	2.88	2.95	2.72	2.93	2.77
Oct. 8	3.22	3.08	3.16	3.10	3.04	2.90	2.84	2.81
Suf, Nov. 4	1.37	1.42	1.33	1.26	1.28	1.30	1.23	1.23
Nov. 7	1.47	1.52	1.43	1.47	1.28	1.35	1.35	1.30
Fam (II), June 10	2.13	2.12	2.12	2.06	2.29	1.89	2.08	2.01
June 13	2.56	2.21	2.35	2.26	2.49	2.15	2.42	2.19
Mih (II), June 22	3.53	3.40	3.33	3.40	3.33	3.22	3.03	3.08
June 25	3.56	3.43	3.43	3.32	3.26	3.15	3.18	3.07
Averages (A)	2.60	2.53	2.50	2.50	2.53	2.38	2.41	2.33
Differences (D)	......	−0.07	−0.10	−0.10	−0.07	−0.22	−0.19	−0.27
Alcohol, dose A:								
Lig, Oct. 1	2.58	2.63	2.48	2.63	2.66	2.54	2.53	2.44
Roj (II), Oct. 6	3.01	2.99	2.77	2.84	2.93	2.73	2.76	2.75
Suf, Nov. 5	1.50	1.26	1.36	1.32	1.34	1.27	1.32	1.27
Fam (II), June 11	2.35	2.17	2.24	2.09	2.15	2.04	2.17	2.06
Mih (II), June 23	3.26	3.27	3.06	3.09	3.23	3.34	3.23	2.98
Averages (A_1)	2.54	2.46	2.38	2.39	2.46	2.38	2.40	2.30
Differences (D_1)	......	−0.08	−0.16	−0.15	−0.08	−0.16	−0.14	−0.24
Alcohol, dose B:								
Lig, Oct. 2	2.73	2.50	2.41	2.58	2.59	2.49	2.61	2.60
Roj (II), Oct. 7	3.04	2.85	3.01	3.08	3.05	2.89	2.68	2.87
Suf, Nov. 6	1.54	1.36	1.26	1.34	1.35	1.39	1.32	1.26
Fam (II), June 12	2.52	2.21	2.21	2.29	2.23	2.12	2.23	2.24
Mih (II), June 24	3.60	2.64	2.87	2.97	3.17	3.18	3.07	3.07
Averages (A_2)	2.69	2.31	2.35	2.45	2.48	2.41	2.38	2.41
Differences (D_2)	......	−0.38	−0.34	−0.24	−0.21	−0.28	−0.31	−0.28
Effect of alcohol, dose A:								
Differences for group (D_1-D)	......	− .01	− .06	− .05	− .01	+ .06	+ .05	+ .03
Contrast for group (A_1-A)	......	− .07	− .12	− .11	− .07	± .00	− .01	− .03
Per cent from differences	......	−0.4	−2.3	−1.9	−0.4	+2.3	+1.9	+1.2
Per cent from contrast	......	−2.8	−4.8	−4.4	−2.8	±0.0	−0.4	−1.3
Effect of alcohol, dose B:								
Differences for group (D_2-D)	......	− .31	− .24	− .14	− .14	− .06	− .12	− .01
Contrast for group (A_2-A)	......	− .22	− .15	− .05	− .05	+ .03	− .03	+ .08
Per cent from differences	......	−11.7	−9.1	−5.3	−5.3	−2.3	−4.5	−0.4
Per cent from contrast	......	− 8.7	−6.0	−2.0	−2.0	+1.3	−1.2	+3.4

SUMMARY FOR EFFECT OF ALCOHOL ON ACCURACY AND SPEED IN TYPEWRITING.

The results for all three typewriting tasks thus point in the same direction: (1) a slight decrease in the speed of typewriting is found, particularly in the first two hours following the ingestion of the alcohol, afterwards becoming indefinite; (2) the alcohol effect on the speed of typewriting in the first 2 hours is not uniformly more pronounced following dose B than after dose A, except in the writing of the nonsense copy, upon which the larger dose seemed to produce definitely stronger influence; (3) the effect upon the percentage of error made in typewriting all kinds of copy is very marked, the increase being from 50 to 100 per cent in the 2-hour interval following ingestion and usually 25 to 40 per cent in the interval 2 to 3½ hours following ingestion. About twice as many errors resulted from dose B as were found after dose A.

Some of the errors made after alcohol were certainly recognized at the time of typing. Under ordinary circumstances many of these would have been corrected and the speed automatically reduced. We will examine variations in the typing speed to note if it was equally smooth after alcohol and the large increase in errors will be further analyzed.

Variability in the Speed of Typewriting.

In dealing with our typewriting data, *the line* has been made the unit and the results have been stated in terms of the average number of errors per line of typewriting and the average number of strokes per second for the line of typewriting. There were 20 lines of practice typewriting, 25 lines of scientific prose, and 10 lines of nonsense copy. The mean variation for the number of strokes per second for the 20 lines of practice writing was determined separately for each period and each subject, and this mean variation was divided by the average number of strokes per second for the 20 lines of the period. In this way the coefficient of variability for the speed of writing the practice sentence was secured in terms of per cent. The same procedure was followed for the scientific prose and the nonsense material. We must content ourselves with publishing a summary table giving the averages, differences, and the alcohol effect for the two doses computed by the two methods which have been used throughout this chapter. The summary table 8 is arranged essentially like the tables which precede it, except that all individual results have been omitted.

The normal percentage of variability differs somewhat with the three kinds of typewriting. When judged by the results obtained in the preliminary period, the variability is 4.5 per cent with the practice sentence, 7.6 per cent with the scientific prose, and 6.4 per cent with the nonsense copy. The lines of practice copy were always of the same length and required the same number of strokes when errors were not made; the same is true for the nonsense copy, so that the difference between variabilities of 4.5 and 6.4 per cent has no other explanation than that the nonsense material was more difficult. In the scientific prose copy, lines differed slightly in the number of strokes required, but a factor of more importance is the unequal difficulty of successive lines of the prose material.

With the practice writing but little change is shown throughout the periods of the control experiment, the averages ranging from 4.4 to 5.6 per cent. The unpublished individual values range from 2.4 (*Roj* II, October 8, period 1) to 10.1 per cent (*Lig*, September 30, period 3). It may immediately be noted that the percentage variability is usually greater after doses A and B than after the control dose. The percentage effect of alcohol as computed by the contrast method for dose A shows an increase in variability by 2, 14, 33, and 27 per cent for periods 2 to 5 in order, but beyond this point, i. e., in the 1½ hours of the last three periods after the dose, the

TABLE 8.—*Summary comparison of the percentage variability in the speed of typewriting.*

Type of data.	Prelim.	Periods following dose.						
	1	2	3	4	5	6	7	8
PRACTICE COPY.								
Control:								
Averages	4.5	4.4	5.1	4.6	5.2	4.8	5.2	5.6
Differences	......	- .1	+ .6	+ .1	+ .7	+ .3	+ .7	+ 1.1
Alcohol, dose A:								
Averages	4.0	4.5	5.8	6.1	6.6	4.7	5.0	6.3
Differences	......	+ .5	+ 1.8	+ 2.1	+ 2.6	+ .7	+ 1.0	+ 2.3
Alcohol, dose B:								
Averages	5.0	5.2	6.7	5.9	4.9	4.5	5.2	4.4
Differences	......	+ .2	+ 1.7	+ .9	- .1	- .5	+ .2	- .6
Effect of alcohol, dose A:								
Per cent from differences	......	+14	+28	+47	+44	+ 9	+ 7	+28
Per cent from contrast	......	+ 2	+14	+33	+27	- 2	- 4	+13
Effect of alcohol, dose B:								
Per cent from differences	......	+ 6	+23	+17	-17	-17	-10	-35
Per cent from contrast	......	+18	+31	+28	- 6	- 6	± 0	-21
SENSE COPY.								
Control:								
Averages	7.6	7.0	7.4	8.2	8.6	9.2	8.1	8.2
Differences	......	- .6	- .2	+ .6	+ 1.0	+ 1.6	+ .5	+ .6
Alcohol, dose A:								
Averages	7.8	7.9	8.1	9.7	8.3	9.0	8.6	8.1
Differences	......	+ .1	+ .3	+ 1.9	+ .5	+ 1.2	+ .8	+ .3
Alcohol, dose B:								
Averages	7.9	7.4	7.9	9.7	10.1	10.0	8.6	8.5
Differences	......	- .5	± .0	+ 1.8	+ 2.2	+ 2.1	+ .7	+ .6
Effect of alcohol, dose A:								
Per cent from differences	......	+ 9	+ 7	+17	- 7	- 5	+ 4	- 4
Per cent from contrast	......	+13	+10	+18	- 4	- 2	+ 6	- 1
Effect of alcohol, dose B:								
Per cent from differences	......	+ 1	+ 3	+15	+15	+ 6	+ 3	± 0
Per cent from contrast	......	+ 6	+ 7	+18	+17	+ 9	+ 6	+ 4
NONSENSE COPY.								
Control:								
Averages	6.4	6.2	8.2	6.3	7.9	6.5	7.0	7.3
Differences	......	- .2	+ 1.8	- .1	+ 1.5	+ .1	+ .6	+ .9
Alcohol, dose A:								
Averages	6.7	8.1	7.4	7.8	7.4	7.3	8.1	8.8
Differences	......	+ 1.4	+ .7	+ 1.1	+ .7	+ .6	+ 1.4	+ 2.1
Alcohol, dose B:								
Averages	6.5	8.1	8.3	8.3	6.8	5.3	7.2	7.1
Differences	......	+ 1.6	+ 1.8	+ 1.8	+ .3	- 1.2	+ .7	+ .6
Effect of alcohol, dose A:								
Per cent from differences	......	+24	-17	+18	-12	+ 8	+12	+18
Per cent from contrast	......	+31	-10	+24	- 6	+12	+16	+21
Effect of alcohol, dose B:								
Per cent from differences	......	+28	± 0	+29	-19	-20	+ 2	- 5
Per cent from contrast	......	+31	+ 1	+32	-14	-19	+ 3	- 3
AVERAGE ALCOHOL EFFECT.								
Dose A:								
Per cent from differences	......	+16	+ 6	+27	+ 8	+ 4	+ 8	+14
Per cent from contrast	......	+15	+ 5	+25	+ 6	+ 3	+ 6	+11
Dose B:								
Per cent from differences	......	+12	+ 9	+20	- 7	-10	- 2	-13
Per cent from contrast	......	+18	+13	+26	- 1	- 5	+ 3	- 7

variability seems to be less or of uncertain direction. With dose B, the situation is similar. The percentage effect by the contrast method is +18, +31, and +28 per cent for periods 2, 3, and 4. Beyond the fourth period the effect is in the opposite direction, that is, a slight decrease in variability to the end of the experiment.

The results for the sense and nonsense copy may be described in much the same way as those for the practice sentence. The sense copy gave variability values in the control experiments ranging from 4.2 to 13.5 per cent for the individual subjects. The group averages have a much narrower range (7.0 to 9.2 per cent) and tend to be larger as the experiment progresses. This tendency, which may be due to fatigue, is shown by all three groups of data. The variabilities following dose A are larger in periods 2, 3, and 4 than in the corresponding periods of the control experiment. Beyond period 4 they are usually slightly smaller. For dose B it so happens that the variabilities are in all the periods larger than the comparable values following the control solution. The effect of alcohol for dose B is therefore plus in all periods, the maximum showing in periods 4 and 5 with an increased variability of from 15 to 18 per cent. With the nonsense copy the results are not so regular with either dose A or B, especially in magnitude, as in the other two groups of data. However, plus values predominate in the first three periods after the alcohol, thus substantiating the data for practice and sense copy in showing a considerable increase in the variability of typewriting speed following the alcohol.

A high grade of skill in any motor coordination is in general associated with a smooth, even flow of performance. For this reason the variability in the speed of typewriting is one way of measuring the excellence of the work. When the variability is stated in terms of per cent, i. e., coefficient of variability, a common basis is given for direct comparison of the performance of each man in each typewriting task. The average alcohol effect for all three typewriting tasks after dose A, computed by the contrast method, is +15, +5, +25, +6, +3, +6, and +11 per cent for periods 2 to 8 inclusive, with an average of +13 per cent in the first 2 hours after alcohol and +7 per cent in the 1½ hours following. The average results for all three typewriting tasks after dose B by the contrast method are +18, +13, +26, and −1 for periods 2 to 5, with an average for this interval of +14 per cent, and an average for the next three periods of −3 per cent. While the two doses of alcohol in this case do not show such a large difference between themselves, with conspicuously larger effects for dose B than for dose A, it nevertheless is clear that the alcohol, especially in the 1½ or 2 hours following its ingestion, produces an increased variability in the speed of typewriting.

INTERVALS OF CONFUSION IN TYPEWRITING PROCESS.

When subjects were writing the sense and nonsense material at the best speed of which they were capable, there often appeared intervals of 0.3, 0.5, and 1 second or even longer when no strokes were made. Such pauses show distinctly on the kymograph record and may easily be distinguished from intervals when the carriage was shifted. These pauses represent confusion in the typewriting process, loss of position in the copy, lapses of attention, a condition of block in the habitual coordinations of typewriting because of error just made, and probably other similar situations. When the copy is difficult and unfamiliar, such blanks may naturally be expected, but they are found to occur also in the kymograph records for the practice-sentence writing. In this case the material was in mind and did not have to be copied from another sheet. The sentence was short and constantly rewritten. Since the practice-sentence writing was absolutely of the same difficulty from period to period, it appears most just in tabulating these intervals of confusion to use this simplest of the typewriting tasks.

The kymograph records for the practice-sentence writing were inspected and it was arbitrarily decided that wherever the line which was made by the Dodge duplex marker showed no deflection for 0.15 second, the blank would be considered a confusion point and measured. There was but one exception to these measurements. Whenever the record showed that two keys had been struck at the same time so that they locked together, this was not counted as a confusion point. The adoption of the same minimum for all subjects was arbitrary, but by this means all the records were treated alike. Two competent individuals went over the records carefully and marked every place where a pause or block of 0.15 second or longer had occurred. A third individual checked these points; they were then measured and the total obtained for each subject and each period. The total number of such blocks that individual subjects showed for different periods varied widely. The range in the control data is from 0 for *Suf*, November 7, period 5, to 35 for *Mih* II, June 22, periods 7 and 8. *Roj* II, *Suf*, and *Fam* II in general averaged four or five such pauses in each period. *Lig* usually showed 12 to 15 and *Mih* II about 18 to 20 per period. Most of these were short. The average number for the preliminary period of control data was 10.5 pauses. The effect of alcohol on the number of such pauses was shown by an increase of approximately 25 per cent in the first two hours after doses A and B.

Of more significance than the number of such occurrences is the time duration which they represent. The totals of all of the time intervals in the practice-sentence writing when progress was blocked and no strokes made for 0.15 second or longer are assembled in table 9. The number of lapses as well as their duration is thus combined in these scores. As seen in the averages for the control data, the total confusion time is normally about 2.60 seconds, increasing somewhat with succeeding periods and finally reaching in the eighth period 3.57 seconds. The preliminary average for the dose A experiments, 2.62 seconds, is much the same as the preliminary average for the control experiments. Following the alcohol, however, the total time increases markedly. The same may be said in reference to the data for the dose B experiments. Here the preliminary average is somewhat higher than the control value but the averages following the alcohol are still higher; in fact, that for period 3 is more than twice as high. The effect of alcohol in the experiments with dose A in terms of differences is +9, +59, +17, and +56 per cent for periods 2 to 5, averaging 35 per cent for the first two hours. Following the fifth period the sign is changed, and the values are much smaller on the average. By the method of contrast the effect for dose A in the first 2 hours after alcohol is slightly smaller, that is, an increase of 32 per cent. Following dose B, the confusion time was especially increased in period 3, the effect being +133 per cent, but this decreased in period 4 to +36 per cent. In the later periods, the percentage effect was most frequently a minus value, indicating some improvement as compared to the condition existing at the end of the control experiments.

TABLE 9.—*Total of all time intervals in the practice-sentence writing during periods of confusion when no stroke was made for 0.15 second or longer.*

Subject, date, and type of experiment.	Sum of confusion intervals during practice typewriting.							
	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
ontrol:	*sec.*	*sec.*	*sec.*	*sec.*	*sec.*	*sec.*	*sec.*	*sec.*
Lig, Sept. 30......	4.84	1.95	8.04	5.87	5.88	5.24	5.29	5.09
Oct. 3......	2.81	5.90	3.35	1.23	1.67	5.26	6.31	4.38
Roj (II), Oct. 5......	2.08	1.96	.97	.55	2.03	2.47	1.80	2.11
Oct. 8......	.43	1.27	1.66	.64	.47	.97	1.25	3.19
Suf, Nov. 4......	1.80	.82	.45	.71	1.90	.25	.59	.59
Nov. 7......	.67	.61	.46	1.00	.00	.93	.44	1.01
Fam (II), June 10......	1.52	1.18	1.48	1.62	4.59	1.71	1.23	.62
June 13......	.70	1.02	2.72	3.26	2.49	5.57	.92	4.28
Mih (II), June 22......	5.63	7.69	6.48	8.01	8.81	7.65	9.07	9.26
June 25......	5.53	3.55	3.42	5.03	3.72	5.57	5.19	5.18
Averages (A).........	2.60	2.60	2.90	2.79	3.16	3.56	3.21	3.57
Differences (D).......	......	± .00	+ .30	+ .19	+ .56	+ .96	+ .61	+ .97
lcohol, dose A:								
Lig, Oct. 1......	2.32	4.12	2.97	5.24	5.96	3.62	4.17	5.71
Roj (II), Oct. 6......	1.58	.65	3.20	.83	4.95	.58	2.36	.95
Suf, Nov. 5......	1.86	.84	.36	.00	.82	.44	.73	1.19
Fam (II), June 11......	.99	.51	.73	1.56	2.71	3.05	2.23	2.92
Mih (II), June 23......	6.36	8.11	14.99	8.67	8.76	8.13	6.76	6.59
Averages (A_1).........	2.62	2.85	4.45	3.26	4.64	3.16	3.25	3.47
Differences (D_1).......	......	+ .23	+ 1.83	+ .64	+ 2.02	+ .54	+ .63	+ .85
lcohol, dose B:								
Lig, Oct. 2......	7.04	5.62	5.97	6.06	5.60	2.36	3.97	5.09
Roj (II), Oct. 7......	.49	3.43	16.90	2.40	1.38	1.53	5.38	1.10
Suf, Nov. 6......	1.15	.72	2.32	.30	.53	.35	.88	1.10
Fam (II), June 12......	.15	1.66	3.24	5.98	.78	1.69	.84	1.00
Mih (II), June 24......	5.62	4.27	5.86	5.65	8.74	7.76	9.21	5.43
Averages (A_2).........	2.89	3.14	6.86	4.08	3.41	2.74	4.06	2.74
Differences (D_2).......	......	+ .25	+ 3.97	+ 1.19	+ .52	− .15	+1.17	− .15
ffect of alcohol, dose A:								
Differences for group (D_1-D)............	......	+23	+153	+ 45	+146	− 42	+ 2	− 12
Contrast for group (A_1-A)............	......	+25	+155	+ 47	+148	− 40	+ 4	− 10
Per cent from differences	......	+ 9	+ 59	+ 17	+ 56	− 16	+ 1	− 5
Per cent from contrast..	......	+10	+ 53	+ 17	+ 47	− 11	+ 1	− 3
ffect of alcohol, dose B:								
Differences for group (D_2-D)............	......	+25	+367	+100	− 4	−111	+56	−112
Contrast for group (A_2-A)............	......	+54	+396	+129	+ 25	− 82	+85	− 83
Per cent from differences	......	+ 9	+133	+ 36	− 2	− 40	+20	− 41
Per cent from contrast..	......	+21	+136	+ 46	+ 8	− 23	+26	− 23

In considering the speed of typewriting, we have endeavored to make an analysis on the basis of the number of strokes per second, the variability in the speed of typewriting successive lines of all three kinds of typewriting, and the pauses or periods of confusion when the subject failed to make strokes and did not progress. From this analysis and without entering the intricate maze of such details as individual typewriting habits with certain letters, letter sequences, words, and phrases, we find that the number of typewriting strokes per second is slightly reduced after alcohol. The even progress of the writing is apparently much more disturbed than the average speed. This has been determined by the coefficients of variability for the speed of writing successive lines in each typewriting task, and by the smoothness of the performance which seems much disturbed by the alcohol. The latter disturbance is exhibited by a large increase in the amount of time when the subject's typewriting processes are confused and blocked, so that he makes no strokes whatever.

PRACTICAL LEGIBILITY OF TYPEWRITTEN COPY AFTER ALCOHOL.

It may fairly be argued that, after all, the practical legibility of the copy which is produced by a typist is the real factor of merit, providing that the time element for the quantity of his work is not greatly altered. Certainly in the everyday office work of these five typists who were studied in the Laboratory, the object was to produce coherent, legible copy without ambiguity or any other difficulty. Undoubtedly in scoring our records of the laboratory performance, some of the errors which we have arbitrarily made of the same weight as the others, such as a double space between two words, are not very serious, since they in no way reduce the legibility of the transcript.

For the sake of argument, we may arbitrarily admit that two of the errors counted in a line of typewriting (see p. 43) regardless of the kind of error, do not seriously decrease the legibility of the copy. If, then, we inspect all of the typewritten sheets which the subject produced on the regular experimental days and count for each page of copy the number of typewritten lines which contain more than two errors, tabulate the data individually, and compute averages as usual, we obtain thereby the data presented in table 10. Only the average results are presented.

With the practice sentence on the control days, it is found that on the average about 2 of the 20 written lines contain more than 2 errors a line. The preliminary periods for dose A and dose B show the same value. In the first 2 hours or so following dose A, the number of lines containing 2 or more errors average from 2.4 to 4.2. In every period except the seventh, the averages are larger following dose A than after the control dose. The effect of the alcohol as computed by the contrast method is +63, +91, +9, +68, +90, −41, and +21 per cent for the various periods in order. After dose B the number of lines with more than 2 errors, instead of being 2, as is found after the control dose and before alcohol, is more nearly 5 lines. Every period following dose B is conspicuously larger than the corresponding period following the control dose. The alcohol effect is quite large and very regular. It is 30 to 60 per cent in the first period following alcohol, which in this case means within 10 minutes of the ingestion of the dose, and approximately +250 per cent in period 3. It falls to about +180 in period 4 and thereafter gradually decreases, except that in period 6 the effect was somewhat larger than in periods 5 or 7. Even at the end of the

TABLE 10.—*Alcohol effect in the three tests on the average number of lines of typewriting with more than two errors per line.*

Type of data.	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
PRACTICE COPY.								
ontrol:								
Averages	1.6	1.6	2.2	2.2	2.5	2.0	3.4	3.3
Differences		± .0	+ .6	+ .6	+ .9	+ .4	+ 1.8	+ 1.7
lcohol, dose A:								
Averages	2.0	2.6	4.2	2.4	4.2	3.8	2.0	4.0
Differences		+ .6	+ 2.2	+ .4	+ 2.2	+ 1.8	± .0	+ 2.0
lcohol, dose B:								
Averages	2.0	2.6	7.4	6.0	4.4	4.2	5.0	4.2
Differences		+ .6	+ 5.4	+ 4.0	+ 2.4	+ 2.2	+ 3.0	+ 2.2
ffect of alcohol, dose A:								
Per cent from differences		+ 33	+ 89	− 11	+ 72	+ 78	−100	+ 17
Per cent from contrast		+ 63	+ 91	+ 9	+ 68	+ 90	− 41	+ 21
ffect of alcohol, dose B:								
Per cent from differences		+ 33	+266	+189	+ 83	+100	+ 67	+ 28
Per cent from contrast		+ 63	+236	+173	+ 76	+110	+ 47	+ 27
SENSE COPY.								
ontrol:								
Averages	3.4	2.4	2.8	3.5	2.7	4.3	3.3	2.8
Differences		− 1.0	− .6	+ .1	− .7	+ .9	− .1	− .6
lcohol, dose A:								
Averages	1.8	3.2	4.4	6.4	4.4	6.6	5.0	4.6
Differences		+ 1.4	+ 2.6	+ 4.6	+ 2.6	+ 4.8	+ 3.2	+ 2.8
lcohol, dose B:								
Averages	3.6	4.2	6.6	8.0	6.0	8.0	5.6	4.4
Differences		+ .6	+ 3.0	+ 4.4	+ 2.4	+ 4.4	+ 2.0	+ .8
ffect of alcohol, dose A:								
Per cent from differences		+ 92	+123	+173	+127	+150	+127	+131
Per cent from contrast		+ 33	+ 57	+ 83	+ 63	+ 54	+ 52	+ 64
ffect of alcohol, dose B:								
Per cent from differences		+ 46	+103	+123	+ 89	+100	+ 60	+ 40
Per cent from contrast		+ 75	+136	+128	+122	+ 86	+ 70	+ 57
NONSENSE COPY.								
ontrol:								
Averages	2.2	1.5	1.6	1.4	1.7	1.9	2.1	2.3
Differences		− .7	− .6	− .8	− .5	− .3	− .1	+ .1
lcohol, dose A:								
Averages	1.2	1.8	2.6	1.8	1.8	2.6	1.8	2.2
Differences		+ .6	+ 1.4	+ .6	+ .6	+ 1.4	+ .6	+ 1.0
lcohol, dose B:								
Averages	1.2	4.0	2.6	3.2	2.2	2.0	2.8	3.0
Differences		+ 2.8	+ 1.4	+ 2.0	+ 1.0	+ .8	+ 1.6	+ 1.8
fect of alcohol, dose A:								
Per cent from differences		+ 77	+118	+ 82	+ 65	+100	+ 41	+ 53
Per cent from contrast		+ 20	+ 63	+ 29	+ 6	+ 37	− 14	− 4
fect of alcohol, dose B:								
Per cent from differences		+206	+118	+165	+ 88	+ 65	+100	+100
Per cent from contrast		+167	+ 63	+129	+ 29	+ 5	+ 33	+ 30
AVERAGE ALCOHOL EFFECT.								
ose A: Per cent from contrast		+ 39	+ 70	+ 40	+ 46	+ 60	− 1	+ 27
ose B: Per cent from contrast		+102	+145	+143	+ 76	+ 67	+ 50	+ 38

experiment, the increase in the number of lines of the practice-sentence copy containing more than 2 errors amounted to 27 per cent.

In the prose copying, a somewhat larger number of lines with more than 2 errors occurred than in writing the practice copy. The preliminary period of the control experiment gives an average of 3.4 lines, which is somewhat larger than appears on the average after the control dose. The preliminary value for dose A is much smaller (1.8 lines) while for dose B it is about the same, 3.6 lines. Without exception in any period, the average after dose A and dose B is larger than that after the control dose. The effect of the alcohol as computed from the differences is large with dose A, this being due to the lower preliminary value with this dose. Probably the direct contrast method of showing the alcohol effect is the more logical in this case. The increase in the number of lines with more than 2 errors after dose A averages 58 per cent for the total period studied after the ingestion of alcohol. The effect was at its maximum, 83 per cent, in period 4. The effect of dose B as computed by the same method increases until it reaches 136 per cent in period 3, then decreases, the averages being 128, 122, 86, 70, and 57 per cent, respectively, from periods 4 to 8. The average increases for the whole 7 periods following dose B is 96 per cent for the sense copy.

The number of lines having more than 2 errors with the nonsense copy average somewhat smaller than either the sense or practice results. In the nature of the case, the nonsense copy had to be written at a much slower speed and did not involve word habits, unless in a negative way, because none of the five-letter combinations closely resembled words. Nevertheless, error combinations were frequent and the effect of alcohol in this case is much like that in the other two typewriting tests. The average number of lines with more than 2 errors is always greater for both doses A and B than after the control solution, except that in periods 7 and 8 after dose A, the averages are not quite so large as those following the ingestion of the control dose. The preliminary values with nonsense writing for both doses A and B are relatively much lower than the average for the control experiments, so that the percentage effects computed from differences are similarly large. By the contrast method of computation, the average alcohol effect after dose A for periods 2 to 6 is an increase of 31 per cent in the number of lines with more than two errors. The highest effect occurred in the third period, in which a change of 63 per cent is noted; in the last two periods (7 and 8) the effect was negative, i. e., −14 and −4. After dose B the strongest effect came in the second period, that is, the first test after alcohol, in which the increase is 167 per cent. The nonsense test was the last of the typewriting tasks and thus came later in the period, being removed from the complete ingestion of the alcohol 20 to 25 minutes. The effect of alcohol after dose B is also prominent in periods 3 and 4, in which it is 63 and 129 per cent, respectively. Smaller increases are shown in all later periods.

The average percentage effect of alcohol computed by the contrast method for all of the three typewriting tasks is given at the bottom of table 10. In the 2 hours following dose A, the average alcohol effect was an increase of 49 per cent in the number of lines containing more than 2 errors, with a maximum occurring in the third period of 70 per cent. The average for periods 6 to 8, that is, 3 to 4½ hours after the alcohol was taken, shows a similar increase of 29 per cent. After dose B the increase in the number of lines with accumulated errors was 117 per cent for the average of periods 2 to 5, with a maximum occurring in the third period of 145 per cent, which decreased only slightly in the fourth period. The average effect in periods 6 to 8 with dose B was an increase of 52 per cent.

When typewriting errors are consecutive, or more than 1 error is made in the same word, or the errors are such that whole words are dropped out or transposed, the factor of illegibility is greatly increased. We have attempted to measure this illegibility and thus estimate the practical excellence of the typewritten copy, by using a method of arbitrarily weighting the errors. For this purpose errors have been classified under three heads: (1) scattered, (2) consecutive, and (3) whole word errors. Under the first, one scattered error in a line is marked 1 demerit; two such errors, 3 demerits; three such errors, 5 demerits; and so on, adding 2 demerits for each added scattered error in the line of typewriting. For consecutive errors, 2 are marked 10 demerits, three 20 demerits, four 40 demerits, and five 60 demerits, and so on, adding 20 demerits for each additional consecutive error. If there were 2 consecutive errors in one word or in one place in the same line, that place would be marked for 10 demerits, and if there were 2 in another place in the line, that place would be marked separately for 10 demerits, and likewise in other cases, the heavy penalty only coming when 4 or 5 errors actually followed immediately after each other. The criticism might be made that really such a case may be subjectively only 1 error, since the typist may have simply lost his "home position" in fingering and be striking each key one place to the left or to the right. This is, of course, true, but practically such an error in any copy which a typist produces is extremely serious and in an office might easily result in his having to retype the whole sheet. Hence, even this situation, which is by no means always the one that accounts for the accumulation of consecutive errors, logically takes a very heavy penalty. Under the third category (whole word errors) 10 demerits were given if 1 word was omitted, repeated, substituted, or 2 words transposed, 20 demerits for 2 words, and 30 demerits for 3 words.

This scheme of weighting the errors and so determining the total illegibility factor for each sheet of typewriting was rigidly applied to all of the practice copy. This copy, since it always involved the same sentence, and thus the same material, and was equally difficult from period to period, and also since it involved the fewest number of word-writing habits from the typist, seems to lend itself best to such a treatment. The results pertaining to the illegibility factor for each subject are presented in table 11 in the usual tabular form. There is a wide variation between the scores of different men and also between the scores of the same subject in different periods. Such a variation is to be expected in the factor under consideration and with the method of weighting which was adopted, since the accidental or incidental character of the phenomena is particularly emphasized. Nevertheless, the averages for the various preliminary periods differ but little. Also, in the periods before and following the control dose there is, considering the circumstances, no great deviation, the range in the averages being from 37 to 64 in the illegibility factor. In the averages following alcohol, with the single exception of period 7 after dose A, the illegibility score is always larger than the corresponding average following the control dose. It is likewise to be observed that the average scores for periods following dose B are larger than the comparison scores following dose A, except in the last period, when they are practically the

TABLE 11.—*Alcohol effect on the illegibility of practice typewriting.*

Subject, date, and type of experiment.	Weighted scores for errors at successive half-hour periods.							
	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
Control:								
Lig, Sept. 30	25	49	46	80	72	60	105	42
Oct. 3	7	35	22	9	48	96	79	54
Roj (II), Oct. 5	38	128	112	80	87	64	131	198
Oct. 8	82	116	177	91	98	99	127	138
Suf, Nov. 4	48	4	27	5	9	3	3	3
Nov. 7	50	4	1	6	5	25	50	21
Fam (II), June 10	5	5	7	32	43	16	47	11
June 13	14	20	39	69	35	16	29	98
Mih (II), June 22	58	30	30	79	33	42	49	56
June 25	44	4	9	17	36	20	16	6
Averages (A)	**37**	**40**	**47**	**47**	**47**	**44**	**64**	**63**
Differences (D)	......	+ 3	+ 10	+ 10	+ 10	+ 7	+ 27	+26
Alcohol, dose A:								
Lig, Oct. 1	34	39	18	36	33	34	26	25
Roj (II), Oct. 6	45	52	308	84	218	145	78	197
Suf, Nov. 5	4	84	17	3	43	54	2	92
Fam (II), June 11	18	38	10	100	63	86	62	74
Mih (II), June 23	53	43	144	33	41	56	28	25
Averages (A_1)	**31**	**51**	**99**	**51**	**80**	**75**	**39**	**83**
Differences (D_1)	......	+20	+ 68	+ 20	+ 49	+ 44	+ 8	+52
Alcohol, dose B:								
Lig, Oct. 2	78	96	163	144	64	70	74	75
Roj (II), Oct. 7	78	132	410	320	391	393	425	248
Suf, Nov. 6	2	28	142	44	11	31	39	50
Fam (II), June 12	7	9	79	113	40	47	54	33
Mih (II), June 24	46	19	106	49	110	12	35	5
Averages (A_2)	**42**	**57**	**180**	**134**	**123**	**111**	**125**	**82**
Differences (D_2)	......	+15	+138	+ 92	+ 81	+ 69	+ 83	+40
Effect of alcohol, dose A:								
Differences for group (D_1-D)	......	+17	+ 58	+ 10	+ 39	+ 37	− 19	+26
Contrast for group (A_1-A)	......	+11	+ 52	+ 4	+ 33	+ 31	− 25	+20
Per cent from differences	......	+50	+171	+ 29	+115	+109	− 56	+76
Per cent from contrast	......	+28	+111	+ 9	+ 70	+ 71	− 39	+32
Effect of alcohol, dose B:								
Differences for group (D_2-D)	......	+12	+128	+ 82	+ 71	+ 62	+ 56	+14
Contrast for group (A_2-A)	......	+17	+133	+ 87	+ 76	+ 67	+ 61	+19
Per cent from differences	......	+30	+320	+205	+178	+155	+140	+35
Per cent from contrast	......	+43	+283	+185	+162	+152	+ 95	+30

same, i. e., 83 and 82. The results are so pronounced they need no emphasis in the text. Following dose A, the factor of illegibility was increased during the first 2 hours after alcohol by 55 per cent as an approximate average. Using the same method, that of contrast, which is here less liable to gross variation, the average change in periods 6 to 8 was 21 per cent. Following dose B the change in the illegibility factor is extremely regular and of conspicuous magnitude. The average for periods 2 to 5 shows an increase of 168 per cent, with a maximum of 283 per cent occurring in the third period, from which the effect decreases until it reaches 30 per cent in the eighth period. The average for periods 6, 7, and 8 is an increase in illegibility amounting to 92 per cent.

If the practical excellence of typewritten material is to be judged on the basis of its freedom from such errors or such groupings of errors as make the contents of the material difficult of understanding, then it must be concluded from this investigation that 21 to 28 grams of alcohol given in a 14 to 22 per cent solution (dose A) reduces the quality of typewriting about 50 per cent for a period extending 2 hours after taking the alcohol on a relatively empty stomach, and continues to affect the typewriting unfavorably to the extent of about 25 per cent in the period from 3 to 4½ hours after the alcohol. The taking of 32 to 42 grams of ethyl alcohol in 150 to 200 c. c. of liquid (dose B) decreases the excellence of the typewritten copy of easy practice-sentence work about 160 per cent as an average in the 2 hours after the taking of the beverage, and as much as 90 per cent even 3 hours after the alcohol is taken. This is clearly shown in table 11, where only the errors from the practice writing are weighted. If, however, reference is made to table 10, we find that even when the results are averaged for the three kinds of typewriting, the values for dose A agree well with the statements made as to the findings for the same dose in table 11. This is not the case with dose B, however, as the average for the first 2 hours after alcohol is 117 per cent when the number of errors in the three kinds of typewriting is counted, whereas when the errors are weighted for the practice sentence, the average effect in this 2-hour period is 168 per cent. This comparison is based upon the computations by the contrast method.

In general, the averages obtained from the weighted errors, based on the practice sentence, are larger by both methods of computation than those found by counting the number of lines having more than two errors, not only when the total averages for all the periods are compared with those for the three kinds of typewriting, but also when compared with the results in table 10 for practice-sentence writing. It is thus evident that the typewriting, viewed from every angle at which it has been possible for us to treat the data in an objective and rigid way, suffers strikingly in legibility as a result of the ingestion of alcohol taken under the conditions used in these experiments.[a] These results for the effect of alcohol on typewriting efficiency are substantiated by the data of Frankfurther[a] and Vernon,[b] both of whom used simplified typewriting tasks in connection with alcohol investigations and found that speed was slightly reduced while errors were prominently increased.

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[a] There are many odd and striking combinations of errors and particularly illegible and curious patches of typewriting, which could be illustrated and discussed at length. These, of course, have psychological interest but they do not lend themselves well to the type of objective treatment and presentation to which the writer is endeavoring to adhere in this monograph.

Effect of Alcohol on Heart-Rate During Typewriting.

All of the pulse data in the typewriting experiments were taken by use of the string galvanometer and body-leads applied to the skin below the armpits. The results obtained give direct records of the heart-rate in contrast to the pulse-rates recorded by other methods in some of the studies reported later in this monograph. The body electrodes were put on at the beginning of a session and worn constantly without discomfort for the 4 or 5 hours of the experiment. The records obtained by this method were very accurate, notwithstanding the considerable muscular activity.[c] The only difficulty arose from the fact that the typewriter on which the subject's fingers were playing was in contact with a direct current of 110 volts, but though many records showed some agitation of the string as a result of charged keys, the legibility was not impaired, and accurate measurements could be made. The technique of the measurements is described more at length on page 10.

As may be seen from the experimental outline, three records of the heart-rate were taken in each period as follows:

(1) *Before the typewriting, with the subjects sitting quietly.* In all such cases the subjects had been quiet for some minutes before the record was begun, and the photographic tracing continued for 15 to 20 seconds. The average pulse-cycle length was determined by dividing the number of cycles on the record into the corresponding number of seconds shown by the time line. The time could be determined accurately, as the speed of the paper was between 15 and 17 mm. per second.

(2) *While the subjects were in their final spurt of typewriting the practice sentence.* This record actually covered the last two lines of the practice-sentence writing with each subject. Since they wrote at different speeds, the time interval represented could not be the same for all. It was in general from 15 to 20 seconds in length and included from 20 to 30 pulse-cycles. These pulse-cycles were all measured individually to 0.1 mm., as were the corresponding time intervals. The average duration of the pulse-cycle was determined and also the mean variation.

(3) *After 30 seconds of relaxation following the completion of the writing of the practice sentence.* When the required number of practice lines had been completed the subject stopped abruptly and sat relaxed with his hands in his lap. After 30 seconds of this relaxation, a record of the heart-rate was begun which continued for 15 to 17 seconds. This record we have termed "recuperation heart-rate." The average cycle length was determined as in the case of the rest pulse. The results after alcohol for the three different records associated with the typewriting will be considered separately and in order.

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[a] Frankfurther, Psychol. Arbeit., 1914, 6, p. 419.

[b] Vernon, Med. Research Com., Sp. Rept., Ser. No. 34, London, 1919.

[c] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 92; also Benedict, Miles, Roth, and Smith, Carnegie Inst. Wash. Pub. No. 280, 1918, p. 151.

HEART-RATE DURING REST.

It is important to bear in mind that the data for heart-rate associated with the typewriting experiments are recorded in terms of pulse-cycle length, i. e., time in 0.01 second between *R* and *R* of the electrocardiographic record. The records are not long (a concession to the 30-minute period), since each covers but 15 to 20 seconds. They are thus open to some criticism, for it is commonly recognized that the heart-rate is variable and a count of 30 or more seconds is often necessary to get a trustworthy result. It will be shown later that during actual typewriting a longer record would have been of little, if any, advantage, since the mean variation between successive pulse-cycles rarely amounts to as much as 10 per cent of the average cycle-length. In our discussion, therefore, increase in cycle-length means a decrease in heart-rate, while a shortening of the cycle-length in time duration means a quickening of heart-rate.

The data for the resting condition preceding typewriting are recorded in table 12, which is the same in form as that used in presenting the typewriting results. For the 10 normal days (2 days with each of the 5 subjects) the average cycle-length quite regularly increases from period to period. Starting at the average initial level of 80.4, it gradually lengthens until at the seventh period the cycle-length is 103.1 seconds. At period 8 the cycle-length has shortened about 1 per cent, but this is probably not significant.

On the days when dose A was taken, the heart cycle-lengths for the preliminary period average 75.6. This shows a heart-rate which is 6 per cent more rapid than that found on the average in the preliminary periods of the normal days. The correspondence is thus fairly good. However, the record for period 2, which followed dose A by 15 minutes or less, shows a change in the average cycle-length to 82.0; hence for this period the alcohol effect as computed by the difference method is in the direction of a slower pulse, whereas in all the following periods the pulse appears to be quickened after alcohol, as the differences from normal are always less than those found in the corresponding control period. The average effect of the alcohol for periods 2 to 8 is −5.7 per cent. When the average heart cycle-lengths after the control dose and dose A, respectively, are directly compared, it is seen that period for period, those after alcohol are invariably shorter, even in period 2, indicating by this method of comparison a faster rate during all periods than on the normal days. The effect of alcohol stated in percentages for the periods in order are −3.0, −9.9, −10.0, −8.4, −14.1, −12.7, and −9.7, with a total average effect of −9.7 per cent. By the difference method, the average effect for periods 2 to 5, inclusive, is −2.8 per cent, whereas by the contrast method, it is −7.8 per cent. The average of these indicates an increase in heart-rate amounting to 5.3 per cent. A similar comparison for the averages of periods 6 to 8 is by differences −9.7 per cent, and by contrast −12.2 per cent, or an increase in heart-rate of about 11 per cent as a result of the smaller dose of alcohol.

The effect of dose B on the heart-rate during rest is likewise indicated in table 12. The preliminary average, 76.8, is within 5 per cent of the preliminary value for normal days. By the method of differences, the alcohol effect for the periods in order are −2.9, −7.8, −7.0, −6.7, −6.5, −14.6, and −3.2, with an average of −7.0 per cent for all the periods following dose B. This is somewhat larger than found for dose A. Disregarding the preliminary and directly contrasting the data for dose B with the normal data, we find the percentage effects to be in order −7.0, −11.1, −10.0, −9.7, −8.7, −14.6, and −6.0 with an average of −9.6 per cent. For the 2-hour interval following ingestion (periods 2 to 5, inclusive) there is an increase in heart-rate represented by an average shortening of the pulse-cycle of −6.1 per cent and by the contrast method of −9.5 per cent, the average of the two methods being 7.8 per cent, as compared with 5.3

TABLE 12.—*Heart-rate with subjects resting quietly in sitting posture.*

Subject, date, and type of experiment.	Average cycle-length in 0.01 second at successive half-hour periods.							
	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
Control:								
Lig, Sept. 30	71	81	96	94	103	117	115	113
Oct. 3	68	79	82	97	97	109	115	107
Roj (II), Oct. 5	81	84	85	89	87	92	94	93
Oct. 8	70	77	85	81	99	89	98	99
Suf, Nov. 4	85	95	87	91	82	101	107	107
Nov. 7	93	93	115	105	111	114	122	110
Fam (II), June 10	75	76	79	88	94	99	104	108
June 13	81	82	78	77	75	83	93	80
Mih (II), June 22	83	86	81	94	83	100	95	100
June 25	97	92	89	93	88	95	88	100
Averages (A)	80.4	84.5	87.7	90.9	91.9	99.9	103.1	101.7
Differences (D)	......	+4.1	+ 7.3	+10.5	+11.5	+19.5	+22.7	+21.3
Alcohol, dose A:								
Lig, Oct. 1	65	78	83	81	91	91	100	109
Roj (II), Oct. 6	73	87	84	94	83	88	86	94
Suf, Nov. 5	71	72	67	72	79	79	91	87
Fam (II), June 11	79	84	76	73	80	86	85	75
Mih (II), June 23	90	89	85	89	88	85	88	94
Averages (A_1)	75.6	82.0	79.0	81.8	84.2	85.8	90.0	91.8
Differences (D_1)	......	+6.4	+ 3.4	+ 6.2	+ 8.6	+10.2	+14.4	+16.2
Alcohol, dose B:								
Lig, Oct. 2	62	71	82	86	89	95	91	106
Roj (II), Oct. 7	81	79	82	86	73	88	86	88
Suf, Nov. 6	87	88	70	74	88	99	92	120
Fam (II), June 12	72	76	70	78	85	90	83	82
Mih (II), June 24	82	79	86	85	80	84	88	82
Averages (A_2)	76.8	78.6	78.0	81.8	83.0	91.2	88.0	95.6
Differences (D_2)	......	+1.8	+ 1.2	+ 5.0	+ 6.2	+14.4	+11.2	+18.8
Effect of alcohol, dose A:								
Differences for group (D_1-D)	......	+2.3	− 3.9	− 4.3	− 2.9	− 9.3	− 8.3	− 5.1
Contrast for group (A_1-A)	......	−2.5	− 8.7	− 9.1	− 7.7	−14.1	−13.1	− 9.9
Per cent from differences	......	+3.0	− 5.0	− 5.5	− 3.7	−11.9	−10.6	− 6.5
Per cent from contrast	......	−3.0	− 9.9	−10.0	− 8.4	−14.1	−12.7	− 9.7
Effect of alcohol, dose B:								
Differences for group (D_2-D)	......	−2.3	− 6.1	− 5.5	− 5.3	− 5.1	−11.5	− 2.5
Contrast for group (A_2-A)	......	−5.9	− 9.7	− 9.1	− 8.9	− 8.7	−15.1	− 6.1
Per cent from differences	......	−2.9	− 7.8	− 7.0	− 6.7	− 6.5	−14.6	− 3.2
Per cent from contrast	......	−7.0	−11.1	−10.0	− 9.7	− 8.7	−14.6	− 6.0

per cent for dose A. The average for periods 6 to 8 shows an increase by differences of 8.1 per cent, and by contrast 9.8 per cent, with an average increase in heart-rate of 8.9 per cent. These results with dose B show a somewhat larger effect after alcohol in the latter part of the experiment, but this temporal relationship is not so prominent as with dose A.

HEART-RATE DURING TYPEWRITING OF PRACTICE SENTENCE.

Prior to the typewriting, the average heart-rate of our group of typists as they sat quietly was 75 to 80 beats per minute (0.80 to 0.75 second in pulse-cycle-length). During the experimental session, the heart-rate gradually decreased, as shown in the average for the 10 normal days, so that in the sixth, seventh, and eighth periods (see table 12) the average cycle-length was about 1 second, representing 60 beats per minute. From table 13 it will be seen that the heart-rate during the work of typewriting is definitely higher than that during rest in that the preliminary level is about 0.67 second per cycle, indicating a per minute heart-rate of approximately 90 beats. As found with the heart-rate during rest, the cycle-length on the normal days gradually increases until the level is approximately 80.0, representing a per minute rate of 75 beats. The typewriting therefore produces a change in the pulse-level of approximately 15 beats per minute.[a]

The preliminary levels for the heart-rate in all three groups, i. e., normal, dose A, and dose B, are practically identical at 67, and therefore the alcohol effect as computed by both methods will be essentially the same, except for the fact that with the difference method the averages of the preliminary values for the normal and alcohol days (66.7 and 67.1) are being used constantly as the base for computing the percentages, whereas with the contrast method the longer pulse-cycle lengths in the successive normal periods are being used as the bases for the respective periods on the alcohol days. Following dose A, all the periods show a faster heart-rate with the alcohol; the maximum effect, 11.5 per cent, is in period 4. The average increase in heart-rate by the method of differences is 5.6 per cent and by contrast 5.9 per cent. A similar identity between the two methods is found when the periods are grouped. Periods 2 to 5 show average increases of 5.4 and 5.9 per cent, while periods 6 to 8 show increases of 5.9 and 6.0 per cent as a result of dose A.

Following dose B, the effect of alcohol on the heart-rate during work is more prominent in periods 2 and 3 than was found relatively for dose A. The maximum appears somewhat later, however (in period 6), whereas with dose A it was present in period 4. The average effect for periods 2 to 8 by the difference method is −8.1 per cent; by contrast the general effect for all periods is −7.1 per cent. Grouping the averages as usual, we find the average change for periods 2 to 5 to be 6.9 and 6.2 per cent by the two methods, with a combined average of 6.5 per cent. For periods 6 to 8, the averages are 9.7 and 8.2 per cent, respectively, with a general average of 9.0 per cent. The effect of alcohol upon the heart-rate with both rest and work and after both doses A and B is relatively stronger in the last group of periods, or what roughly represents the second half of the experimental day.

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[a] Carpenter (Journ. Biol. Chem., 1911, 9, p. 231) found that metabolism during typewriting was increased 30 to 70 per cent with the subject writing at rates of 57 to 115 words per minute.

TABLE 13.—*Heart-rate during or immediately following rapid typewriting.*

Subject, date, and type of experiment.	Average cycle-length in 0.01 second at successive half-hour periods.							
	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
Control:								
Lig, Sept. 30	60	70	74	76	75	85	83	81
Oct. 3	57	66	73	76	72	75	86	82
Roj (II), Oct. 5	72	72	79	83	83	82	78	82
Oct. 8	66	65	71	76	72	79	73	77
Suf, Nov. 4	57	62	68	68	75	75	77	77
Nov. 7	66	69	75	79	84	84	79	85
Fam (II), June 10	70	70	72	88	79	84	85	83
June 13	69	72	73	73	73	70	78	79
Mih (II), June 22	76	76	90	79	80	94	86	86
June 25	78	72	76	78	78	79	72	77
Averages (A)	67.1	69.4	75.1	77.6	77.1	80.7	79.7	80.9
Differences (D)	......	+2.3	+ 8.2	+10.5	+10.0	+13.6	+12.6	+13.8
Alcohol, dose A:								
Lig, Oct. 1	59	67	69	67	83	77	82	84
Roj (II), Oct. 6	69	70	73	74	75	77	82	74
Suf, Nov. 5	57	62	57	66	68	70	74	75
Fam (II), June 11	66	63	70	67	68	72	70	72
Mih (II), June 23	80	80	83	71	73	74	72	79
Averages (A_1)	66.2	68.4	70.4	69.0	73.4	74.0	76.0	76.8
Differences (D_1)	......	+2.2	+ 4.2	+ 2.8	+ 7.2	+ 7.8	+ 9.8	+10.6
Alcohol, dose B:								
Lig, Oct. 2	58	64	67	77	78	77	80	73
Roj (II), Oct. 7	73	73	73	76	74	74	75	76
Suf, Nov. 6	58	63	60	68	76	74	81	78
Fam (II), June 12	74	69	64	64	67	66	68	74
Mih (II), June 24	72	67	77	78	67	68	70	73
Averages (A_2)	67.0	67.2	68.2	72.6	72.4	71.8	74.8	74.8
Differences (D_2)	......	+0.2	+ 1.2	+ 5.6	+ 5.4	+ 4.8	+ 7.8	+ 7.8
Effect of alcohol, dose A:								
Differences for group ($D_1 - D$)	......	−0.1	− 3.8	− 7.7	− 2.8	− 5.8	− 2.8	− 3.2
Contrast for group ($A_1 - A$)	......	−1.0	− 4.7	− 8.6	− 3.7	− 6.7	− 3.7	− 4.1
Per cent from differences	......	−0.2	− 5.7	−11.5	− 4.2	− 8.7	− 4.2	− 4.8
Per cent from contrast	......	−1.4	− 6.3	−11.1	− 4.8	− 8.3	− 4.6	− 5.1
Effect of alcohol, dose B:								
Differences for group ($D_2 - D$)	......	−2.1	− 6.8	− 4.9	− 4.6	− 8.8	− 4.8	− 6.0
Contrast for group ($A_2 - A$)	......	−2.2	− 6.9	− 5.0	− 4.7	− 8.9	− 4.9	− 6.1
Per cent from differences	......	−3.1	−10.1	− 7.3	− 6.9	−13.1	− 7.2	− 8.9
Per cent from contrast	......	−3.2	− 9.2	− 6.4	− 6.1	−11.0	− 6.1	− 7.5

The records of the heart-rate taken during the work of typewriting were measured for individual pulse-cycles. These were entered separately, averaged, and the mean variation computed in each case. The data do not indicate that any progressive change was taking place during the interval when the pulse was recorded.

Effect of Alcohol on Recuperation Heart-rate.

When the subject had finished the writing of the practice sentence and had been sitting quietly for 30 seconds, the heart-rate had returned to nearly the same level that it had shown prior to the typewriting.[a] A comparison of the average cycle-lengths for the various periods on the normal days during resting and during recuperation is as follows:

Period No.	1	2	3	4	5	6	7	8
During rest	80.4	84.5	87.7	90.9	91.9	99.9	103.1	101.7
Recuperation	80.0	85.1	88.1	94.5	94.2	98.8	98.3	97.7

The heart cycle-lengths shown in this comparison of period values are so nearly the same that it might be judged that we have to do here with simply heart-rate during rest. It will be noted, though, from table 14, that the recuperation rate is a little higher during the latter part of the normal experimental day, and also that the preliminary values on the days with dose A and dose B are both shorter than with the heart-rate during rest. In fact, the preliminary value preceding alcohol is so short in comparison with the average for the normal days that the alcohol effect by the difference method is not large and not always consistent. For dose A there is a slight increase in heart-rate for periods 2 to 6, inclusive, with slightly slower heart-rate in periods 7 and 8. The average for the entire experimental session is an increase in rate of 1.8 per cent. By direct comparison, the alcohol effect for dose A appears here to be considerably larger and is always in the same direction, the average effect being −8.7 per cent. By a combination of both methods, difference and contrast, the percentage effects for periods 2 to 5, inclusive, is equivalent to an increase in pulse frequency of 5.7 per cent, while for periods 6 to 8, inclusive, the increase in rate is 4.6 per cent.

The average value for the preliminary period on the days with dose B is 72.8, which is slightly lower than that on the days with dose A, but the effect of the alcohol is greater than with the smaller dose. All of the periods show percentage change in the direction of a faster heart-rate, the average by the difference method being 6.4 per cent. By the method of direct contrast, the effect due to the alcohol is larger, 12.9 per cent. During the 2 hours following dose B (periods 2 to 5), the average increase in heart-rate amounted by the difference method to 6.3 per cent, by the contrast method to 13.2 per cent or combined, approximately a 10 per cent increase in heart-rate. The average for periods 6 to 8 by differences is 6.6 per cent and by comparison 12.4 per cent, with a joint average effect of 9.5 per cent. For the recuperation heart-rate, the effect of alcohol is practically the same for both halves of the experimental session, whereas with the heart-rate during rest and work, the effect of alcohol has been larger in the second half of the session.

One of the very important contributions from the study of Dodge and Benedict[b] was the establishment of a relative acceleration effect of alcohol on the heart-rate. For the pulse during rest they found that the cycle-length was shortened 5.3 per cent as compared with the pulse-rate in control experiments. The average effect of alcohol in their experiments, in which pulse-records were taken in connection with mental and physical work, is an increase in rate of 3 per cent. In our tables 12, 13, and 14

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[a] The slowing of the heart is normally very prompt at the cessation of mild physical work. For pertinent data on the change in pulse-rate immediately following a 24-minute period of walking on a treadmill, see Benedict, Miles, Roth, and Smith (Carnegie Inst. Wash. Pub. No. 280, 1919, pp. 424–440). Even after a short period (6 to 10 seconds) of intense work, as in chinning the bar, the pulse-rate in normal subjects will return to about the pre-working level after 30 seconds. (See pages 415 to 418, and especially figure 92, of the publication noted above.)

Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 231.

TABLE 14.—*Heart-rate after 30 seconds of rest, sitting quietly, following the typewriting of the practice sentence.*

Subject, date, and type of experiment.	Average cycle-length in 0.01 second at successive half-hour periods.							
	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
Control:								
Lig, Sept. 30	73	94	95	98	103	107	111	102
Oct. 3	73	79	85	112	112	108	104	108
Roj (II), Oct. 5	83	81	87	99	93	102	89	97
Oct. 8	74	72	83	80	85	85	82	83
Suf, Nov. 4	75	87	94	103	89	105	110	110
Nov. 7	99	89	93	104	111	106	116	107
Fam (II), June 10	75	88	88	88	89	94	95	94
June 13	72	74	79	84	83	100	94	94
Mih (II), June 22	88	100	89	94	89	94	94	94
June 25	88	87	88	83	88	87	88	88
Averages (A)	80.0	85.1	88.1	94.5	94.2	98.8	98.3	97.7
Differences (D)	......	+ 5.1	+ 8.1	+14.5	+14.2	+18.8	+18.3	+17.7
Alcohol, dose A:								
Lig, Oct. 1	68	79	81	96	97	102	98	106
Roj (II), Oct. 6	72	77	84	83	87	91	92	86
Suf, Nov. 5	66	81	73	81	82	77	103	101
Fam (II), June 11	72	75	74	75	86	80	86	91
Mih, June 23	88	79	88	82	81	81	82	81
Averages (A_1)	73.2	78.2	80.0	83.4	86.6	86.2	92.2	93.0
Differences (D_1)	......	+ 5.0	+ 6.8	+10.2	+13.4	+13.0	+19.0	+19.8
Alcohol, dose B:								
Lig, Oct. 2	61	73	86	74	80	82	79	84
Roj (II), Oct. 7	81	78	82	92	86	88	87	90
Suf, Nov. 6	72	77	72	80	84	90	104	104
Fam (II), June 12	72	73	70	72	75	76	84	88
Mih (II), June 24	78	70	80	83	83	79	78	78
Averages (A_2)	72.8	74.2	78.0	80.2	81.6	83.0	86.4	88.8
Differences (D_2)	......	+ 1.4	+ 5.2	+ 7.4	+ 8.8	+10.2	+13.6	+16.0
Effect of alcohol, dose A:								
Differences for group (D_1-D)	......	− 0.1	− 1.3	− 4.3	− 0.8	− 5.8	+ 0.7	+ 2.1
Contrast for group (A_1-A)	......	− 6.9	− 8.1	−11.1	− 7.6	−12.6	− 6.1	− 4.7
Per cent from differences	......	− 0.1	− 1.7	− 5.6	− 1.0	− 7.6	+ 0.9	+ 2.7
Per cent from contrast	......	− 8.1	− 9.2	−11.8	− 8.1	−12.8	− 6.2	− 4.8
Effect of alcohol, dose B:								
Differences for group (D_2-D)	......	− 3.7	− 2.9	− 7.1	− 5.4	− 8.6	− 4.7	− 1.7
Contrast for group (A_2-A)	......	−10.9	−10.1	−14.3	−12.6	−15.8	−11.9	− 8.9
Per cent from differences	......	− 4.8	− 3.8	− 9.3	− 7.1	−11.3	− 6.2	− 2.2
Per cent from contrast	......	−12.8	−11.5	−15.1	−13.4	−16.0	−12.1	− 9.1

which give the pulse data collected with typewriting, the cycle-length as seen in the averages for all control experiments progressively increases throughout the day. After alcohol the rate is no faster than that in the preliminary period which preceded the dose, but the progressive slowing in rate is much less. In other words, again a relative acceleration effect is found, but the percentage change is larger. It is thus seen that the results are all in the direction of a faster heart-rate after alcohol, the average percentages being as follows:

Periods.	Dose.	Rest.	Work.	Recuperation.
2 to 5:	A	5.3	5.6	5.7
	B	7.8	6.5	9.7
6 to 8:	A	11.0	5.9	4.6
	B	8.9	9.0	9.5

The alcohol effect on the heart-rate is stronger with dose B than with dose A and is about equally strong 2 to 3½ hours after ingestion, as in the first 2 hours. The fact that the heart-rate is quickened after alcohol, whereas the demands are supposedly the same as in the control experiments, is interpreted as a decrease in physiological efficiency. Data in later chapters will add to the evidence for the influence of alcohol on the heart-rate.

Effect of Alcohol on Protective Lid Reflex.

Comparative data of this measurement are available for only four of our typists. *Mih* II had a refractory lid reflex, and even a loud sharp noise, such as is made by the discharge of a pistol cap, would scarcely cause the subject to wink perceptibly after the first two or three trials. As previously stated in the description of the technique (see p. 13), the first reflex is uncomplicated in most cases by voluntary winking. In many instances, however, the blinking follows the first reflex and interferes with the second one. For various reasons the number of records obtained with this reflex in one period (4) is so limited that it is not worth while to present the complicated data for the reflex which was produced by the second stimulus.

Latency of Lid Reflex.

The latency of the protective lid reflex as recorded by our technique usually ranges between 28 and 40 σ, with a mean of about 37 σ. In general it is true, as with the patellar reflex, that large amplitude and short latency are associated on the one hand, and long latency and small amplitude on the other. The objective records for the protective lid reflex, as for the patellar reflex, are very clear and legible, but the events are represented by curves and we are confronted with a serious difficulty in establishing exactly the point on the curve where the line leaves horizontal, indicating the commencement of muscular response.

In table 15, for the latency of the protective lid reflex, the preliminary period on normal days shows latencies which range from 26 to 46 σ, with an average of 38 σ. The averages for the periods which followed the control dose were in order 37, 38, 37, 36, 35, 37, and 37 σ. It so happened that the latency obtained previous to dose A is 36 σ, which is longer than the general average for the period immediately following dose A. In terms of per cent, when computed by the method of preliminary differences, there was no perceptible effect of the alcohol in period 2. In periods 3 to 8 in order, the latencies were apparently lengthened by the alcohol +5.4, +10.8, +10.8, +27.0, +2.7, and +10.8 per cent, with a total average for periods 2 to 8 of +9.6 per cent. The large effect in period 6 (+27 per cent) is in great part due to the abnormally long latency (54 σ) shown by *Fam* II. The average amplitude for these records was small, 2.5 mm. (see table 16, p. 80) that is, smaller than the same subject showed in any other period on June 11. There is at hand no good reason for discarding the records, since aside from latency they demonstrate no irregularity.

Table 15.—*Latency of the protective lid reflex as influenced by alcohol.*

Subject, date, and type of experiment.	Lid-reflex latency in 0.001 second taken at successive half-hour interval							
	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
Control:	σ	σ	σ	σ	σ	σ	σ	σ
Lig, Sept. 30	26	24	26	25	24	25	26	26
Oct. 3	30	31	30	25	29	31	28	35
Roj (II), Oct. 5	38	34	43	44	43	40	42	41
Oct. 8	46	41	39	45	39	45	41	42
Suf, Nov. 4	42	47	44	40	41	37	37	37
Nov. 7	38	44	38	36	34	31	37	34
Fam (II), June 10	42	39	39	40	35	36	43	42
June 13	39	35	47	44	45	37	41	38
Averages (A)	38	37	38	37	36	35	37	37
Differences (D)	......	− 1	±0	− 1	− 2	− 3	−1	− 1
Alcohol, dose A:								
Lig, Oct. 1	25	29	26	28	29	27	27	27
Roj (II), Oct. 6	38	40	44	45	41	48	40	47
Suf, Nov. 5	42	41	41	37	35	41	36	39
Fam (II), June 11	38	31	40	47	46	54	39	42
Averages (A_1)	36	35	38	39	38	43	36	39
Differences (D_1)	......	− 1	+2	+ 3	+ 2	+ 7	±0	+ 3
Alcohol, dose B:								
Lig, Oct. 2	24	29	28	26	30	30	26	33
Roj (II), Oct. 7	37	42	38	44	42	37	40	43
Suf, Nov. 6	49	45	43	43	42	43	43	47
Fam (II), June 12	37	43	40	40	42	46	44	31
Averages (A_2)	37	40	37	38	39	39	38	39
Differences (D_2)	......	+ 3	±0	+ 1	+ 2	+ 2	+1	+ 2
Effect of alcohol, dose A:								
Differences for group (D_1-D)	......	± 0	+2	+ 4	+ 4	+10	+1	+ 4
Contrast for group (A_1-A)	......	− 2	±0	+ 2	+ 2	+ 8	−1	+ 2
Per cent from differences	......	± 0.0	+5.4	+10.8	+10.8	+27.0	+2.7	+10.
Per cent from contrast	......	− 5.4	±0.0	+ 5.4	+ 5.6	+22.8	−2.7	+ 5.
Effect of alcohol, dose B:								
Differences for group (D_2-D)	......	+ 4	±0	+ 2	+ 4	+ 5	+2	+ 3
Contrast for group (A_2-A)	......	+ 3	−1	+ 1	+ 3	+ 4	+1	+ 2
Per cent from differences	......	+10.8	±0.0	+ 5.4	+10.8	+13.5	+5.4	+ 8.
Per cent from contrast	......	+ 8.1	−2.6	+ 2.7	+ 8.3	+11.4	+2.7	+ 5.

The first period average on the days with dose A is 2 σ shorter than the preliminary average for the control days, which is sufficient to exercise a considerable influence upon the percentage effect of alcohol as computed by the difference method, with an average for all the periods of +9.6. When the averages in table 15 for the periods following the control dose and dose A, respectively, are directly contrasted, the alcohol values show longer latencies only in periods 4, 5, 6, and 8, while in periods 2, 3, and 7, the alcohol latencies are as short or a little shorter than the normal. If one averages the whole group of periods 2 to 8, the average effect is found to be +4.4 per cent. By our usual method of combining the two averages, then, we may assume that the effect of dose A was, in general, to lengthen the latency of the protective lid reflex by about 7 per cent. For the 2-hour period following dose A (periods 2 to 5, inclusive) the difference method shows an average effect of +6.8 per cent, the contrast method shows +1.4 per cent, the combined average being +4.1 per cent. A similar comparison of the averages of periods 6 to 8 shows +13.5 and +8.5 per cent, with an average of +11 per cent. As we have seen, the computed effect for the latter part of this comparison is especially influenced by the results in period 6 for one man.

The preliminary average for dose B is 37 σ. The computation of the alcohol effect by the two methods will therefore in this case be a little closer to each other than the values obtained for dose A by like computations. Since it may be observed from table 15 that there is no marked deviation in the average of any one period from the averages of the other, it may be assumed that the results which are computed will be somewhat more trustworthy than those with dose A. On the basis of preliminary differences, the percentage effect of alcohol for the various periods following dose B is represented by these values: +10.8, ±0, +5.4, +10.8, +13.5, +5.4, and +8.1 per cent, the average for the 7 periods which followed the dose being +7.7 per cent. When the alcohol performance is contrasted directly with the normal performance, the percentage changes are +8.1, −2.6, +2.7, +8.3, +11.4, +2.7, and +5.4 per cent. The average is +5.1 per cent. By the combined method, the average effect is therefore an increase of 6.4 per cent in the latency of the lid reflex following dose B. In the first 2 hours following ingestion (periods 2 to 5), the difference method gives an effect of +6.8 per cent and by contrast +4.1 per cent, with an average increase in latency of 5.5 per cent. The second 2-hour period, periods 6 to 8, inclusive, by differences shows +9.0 per cent, by contrast +6.5 per cent. The average change is +7.8 per cent. Dose B thus shows a consistently larger effect in the first 2 hours after ingestion than is found with dose A, but the latter, due to the irregularity mentioned, has seemingly a stronger influence in the second 2 hours after ingestion.

AMPLITUDE OF LID REFLEX.

In the amplitude of response, the protective lid reflex varies percentage-wise more widely than in latency. As will be seen from data presented by Dodge and Benedict,[a] the amplitude ranges between approximately 30 mm. and zero. With our subjects, and as a usual thing after a day or two of experience, the reflex which is elicited by the stimulus apparatus is not a complete closure of the eye, but rather a slight lowering of the lid which amounts to perhaps one-third closure. The largest average reflexes that individual subjects demonstrated were about 12 mm. in our data. As seen in table 16, the group averages for the various periods on normal days are fairly consistent at a total average of about 4.4 mm. The preliminary value is 4.5, while the preliminary for the dose A day is 4.8, but aside from this difference in the preliminary level, the amplitudes following dose A are, with one exception, smaller than those following the control dose. When the amplitude is small, as in this case, a change of 1 or 2 mm. makes a rather large change in terms of per cent. By the method of differences, the results for dose A show an average decrease in size of response amounting to −19.6 per cent; the average percentage effect by direct contrast is −12.6 per cent in size of response. By both methods of computation there appears to be an increase in size of response occurring

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 63, table 4.

TABLE 16.—*Amplitude of the protective lid reflex as influenced by alcohol.*

Subject, date, and type of experiment.	Lid-reflex amplitude measured at half-hour periods.							
	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
Control:	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Lig, Sept. 30	10.8	12.0	6.1	9.1	10.2	8.8	8.5	10.2
Oct. 3	2.1	2.1	3.4	6.1	6.9	5.0	4.0	3.5
Roj (II), Oct. 5	1.0	2.5	1.4	1.2	1.2	1.3	1.4	2.7
Oct. 8	3.6	2.2	3.7	3.0	2.7	2.5	1.5	3.4
Suf, Nov. 4	3.3	1.8	1.2	2.0	2.0	2.4	2.2	2.2
Nov. 7	1.5	1.4	2.1	3.1	2.2	2.4	2.6	1.2
Fam (II), June 10	7.3	6.5	7.0	6.5	5.7	5.2	5.2	4.7
June 13	6.2	11.0	4.2	3.9	4.3	5.8	10.0	6.5
Averages (A)	4.5	4.9	3.6	4.4	4.4	4.2	4.4	4.3
Differences (D)	......	+ 0.4	− 0.9	− 0.1	− 0.1	− 0.3	− 0.1	− 0.2
Alcohol, dose A:								
Lig, Oct. 1	10.2	5.0	9.9	7.3	7.8	6.0	6.0	8.0
Roj (II), Oct. 6	0.6	0.1	1.1	1.0	2.0	0.4	1.2	0.4
Suf, Nov. 5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0
Fam (II), June 11	7.2	7.7	7.2	4.5	6.3	2.5	5.5	5.5
Averages (A_1)	4.8	3.5	4.8	3.5	4.3	2.5	3.4	4.0
Differences (D_1)	......	− 1.3	± 0.0	− 1.3	− 0.5	− 2.3	− 1.4	− 0.8
Alcohol, dose B:								
Lig, Oct. 2	10.7	3.5	6.0	7.7	6.5	7.5	11.5	6.2
Roj (II), Oct. 7	3.6	1.4	1.5	1.0	2.0	1.4	3.0	1.4
Suf, Nov. 6	0.9	1.0	1.2	1.5	1.0	0.8	1.1	1.4
Fam (II), June 12	9.0	4.2	8.2	6.3	6.0	3.9	8.0	6.0
Averages (A_2)	6.1	2.5	4.2	4.1	3.9	3.4	5.9	3.8
Differences (D_2)	......	− 3.6	− 1.9	− 2.0	− 2.2	− 2.7	− 0.2	− 2.3
Effect of alcohol, dose A:								
Differences for group ($D_1 - D$)	......	− 1.7	+ 0.9	− 1.2	− 0.4	− 2.0	− 1.3	− 0.6
Contrast for group ($A_1 - A$)	......	− 1.4	+ 1.2	− 0.9	− 0.1	− 1.7	− 1.0	− 0.3
Per cent from differences	......	−37.0	+19.5	−26.1	− 8.7	−43.4	−28.2	−13.0
Per cent from contrast	......	−28.6	+33.3	−20.4	− 2.3	−40.5	−22.7	− 7.0
Effect of alcohol, dose B:								
Differences for group ($D_2 - D$)	......	− 4.0	− 1.0	− 1.9	− 2.1	− 2.4	− 0.1	− 2.1
Contrast for group ($A_2 - A$)	......	− 2.4	+ 0.6	− 0.3	− 0.5	− 0.8	+ 1.5	− 0.5
Per cent from differences	......	−75.5	−18.8	−35.8	−39.6	−45.3	− 1.9	−39.6
Per cent from contrast	......	−49.0	+16.7	− 6.8	−11.4	−19.0	+34.1	−11.6

in the third period; otherwise the signs for the 7 periods are all in the same direction, and the average result by both methods of computation would be a decrease in amplitude amounting to 16.1 per cent following dose A.

The preliminary value for dose B happened to be the largest average amplitude of any period, 6.1 mm. This is unfortunate and shows again the difficulty in presenting the alcohol effect uncomplicated by extraneous conditions. Since the preliminary value is so high and the averages following the taking of dose B are as small or smaller than those following dose A, which were seen to be smaller than after the control dose, the effect as computed by the preliminary difference method is large and all the signs must necessarily be in one direction. For periods 2 to 8, inclusive, the percentage effects as computed in this way are −75.5, −18.8, −35.8, −39.6, −45.3, −1.9, and −39.6 per cent, the average being −36.6 per cent. When the effect of the alcohol is computed by direct comparison, it will be seen from table 16 that the amplitudes in periods 3 and 7 are considerably larger following dose B than they were following the control dose; hence for these two periods the results are in the opposite direction and amount, respectively, to +16.7 and +34.1 per cent. For the other 5 periods the alcohol amplitudes are smaller, ranging from −6.8 per cent in period 4 to −49.0 per cent in period 2. The signs are therefore 5 : 2 in favor of a decrease in amplitude of reflex following dose B. If we average the values for the percentage effects in the 7 periods following ingestion, we obtain −6.7 per cent, which is considerably different from the former average of −36.6 produced by the method of preliminary differences. The data strongly indicate that the effect of alcohol in reducing the amplitude of the protective lid reflex is of considerable magnitude, but the measurements present so much inherent variability that it is difficult to set an actual value.

The increased latency and decreased response found for the protective lid reflex after alcohol in this series is in full agreement with results for the same measurement in former alcohol publications from the Nutrition Laboratory.

Effect of Alcohol on Finger Movements.

As used in the studies on alcohol and described on p. 16, a finger movement consists of both phases (extension and flexion)—that is, a complete oscillation. From Dodge and Benedict's[a] data it will be found that their subjects, on the average, could perform in 6 seconds 35.8 finger movements. The range was between 27.8 and 45.3 movements. The man showing the smallest rate was their subject VI; Miles[b] made further experiments on this subject and also found he could perform in 6 seconds an average of but 28.4 finger oscillations. These quoted data are for normal or non-alcohol conditions.

In the nature of the case, trained typists may be expected to do this test somewhat better than an ordinary subject, since there are certain similarities between the finger-movement test and the fingering of the typewriter keys; thus the measurement may be considered a closely related process to typewriting. It is no special surprise to find in table 17 that the four typists on whom this test was made show an average for their preliminary value on the normal days of 42.7 movements, which is about 19 per cent faster than the average for the subjects of Dodge and Benedict. It is rather remarkable, however, that their performance in this test is so consistent throughout, the preliminary averages being for the three groups, 42.7, 42.9, and 42.5 oscillations. The successive periods for the normal days show slight variation in their averages; the range is from 42.3 to 43.7 movements, which is a variation of about 3 per cent. Following both doses of alcohol there was a slight but consistent decrease in the number of finger movements which could be executed.

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1919, p. 182, table 30.

[b] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 86, table 15.

TABLE 17.—*Number of finger-movement oscillations performed in 6 seconds.*

Subject, date, and type of experiment.	Speed of finger movement tested at successive half-hour periods.							
	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
Control:								
Roj (II), Oct. 5	41.6	40.8	40.3	41.0	42.0	39.6	40.4	40.5
Oct. 8	43.5	40.8	38.6	42.0	43.8	42.8	43.0	41.8
Suf, Nov. 4	38.6	39.3	39.0	37.5	38.8	39.2	40.5	40.5
Nov. 7	37.5	39.3	38.8	39.5	40.4	39.5	39.8	38.5
Fam (II), June 10	37.7	38.0	38 3	38.0	39.0	38.2	38.0	38.3
June 13	38.0	39.5	39.0	36.4	38.5	39.8	38.5	39.0
Mih (II), June 22	53.0	54.0	53.5	51.2	53.5	51.0	51.5	52.7
June 25	52.0	55.5	52.5	52.5	53.5	54.2	54.0	52.0
Averages (A)	42.7	**43.4**	**42.5**	**42.3**	**43.7**	**43.1**	**43.2**	**42.9**
Differences (D)	......	**+0.7**	**−0.2**	**−0.4**	**+1.0**	**+0.4**	**+0.5**	**+0.2**
Alcohol, dose A:								
Roj (II), Oct. 6	41.8	40.2	40.8	41.0	41.5	42.0	41.5	42.0
Suf, Nov. 5	39.5	37.9	36.8	37.3	38.0	38.7	37.0	37.4
Fam (II), June 11	39.3	37.8	39.0	37.5	39.4	37.7	38.5	38.2
Mih (II), June 23	51.0	50.0	51.0	51.0	51.5	52.6	52.0	51.7
Averages (A_1)	42.9	**41.5**	**41.9**	**41.7**	**42.5**	**42.7**	**42.2**	**42.3**
Differences (D_1)	......	**−1.4**	**−1.0**	**−1.2**	**−0.4**	**−0.2**	**−0.7**	**−0.6**
Alcohol, dose B:								
Roj (II), Oct. 7	43.2	40.2	40.6	38.4	40.0	39.6	39.4	39.0
Suf, Nov. 6	37.7	37.2	37.0	33.3	36.4	37.3	37.0	36.6
Fam (II), June 12	38.3	38.5	40.0	40.5	40.0	39.0	41.6	39.8
Mih (II), June 24	50.6	48.7	51.1	50.7	48.8	51.5	51.0	49.8
Averages (A_2)	42.5	**41.1**	**42.1**	**40.7**	**41.3**	**41.8**	**42.2**	**41.3**
Differences (D_2)	......	**−1.4**	**−0.4**	**−1.8**	**−1.2**	**−0.7**	**−0.3**	**−1.2**
Effect of alcohol, dose A:								
Differences for group (D_1-D)	......	−2.1	−0.8	−0.8	−1.4	−0.6	−1.2	−0.8
Contrast for group (A_1-A)	......	−1.9	−0.6	−0.6	−1.2	−0.4	−1.0	−0.6
Per cent from differences	......	**−4.9**	**−1.9**	**−1.9**	**−3.3**	**−1.4**	**−2.8**	**−1.9**
Per cent from contrast	......	**−4.4**	**−1.4**	**−1.4**	**−2.7**	**−0.9**	**−2.3**	**−1.4**
Effect of alcohol, dose B:								
Differences for group (D_2-D)	......	−2.1	−0.2	−1.4	−2.2	−1.1	−0.8	−1.4
Contrast for group (A_2-A)	......	−2.3	−0.4	−1.6	−2.4	−1.3	−1.0	−1.6
Per cent from differences	......	**−4.9**	**−0.5**	**−3.3**	**−5.2**	**−2.6**	**−1.9**	**−3.3**
Per cent from contrast	......	**−5.3**	**−0.9**	**−3.8**	**−5.5**	**−3.0**	**−2.3**	**−3.7**

With dose A, the difference method gives a minus effect in all periods, ranging in size from 1.4 to 4.9 per cent, with an average decrease for the 7 periods of 2.6 per cent. When computed by the contrast method, period for period, it is again found that all the signs are minus, with the values ranging in size from 0.9 to 4.4 per cent, averaging for the 7 periods −2.1 per cent. Computed by both methods, there is an average decrease of 2.3 per cent in speed of finger movement. In the 2-hour interval following ingestion, the change is by differences 3.0 per cent and by contrast 2.5 per cent with an average of 2.8 per cent. The average for the subsequent 1½ hours is 1.8 per cent, indicating a return in the direction of normality.

The finger-movement results of dose B for the four typists on whom there are comparable data show very concordant results, both by difference and contrast methods. All signs for the various periods are in the same direction, indicating a decreased speed of finger movement. On the basis of differences, the percentage change ranges from 0.5 to 5.2, with an average for the 7 periods of 3.1 per cent, whereas the average by the method of contrast is 3.5 per cent. Dividing the interval following ingestion in the usual way, i. e., averaging the results for periods 2 to 5 and 6 to 8, it is seen that the combined method gives us decreases in number of finger movements of 3.7 and 2.8 per cent in contrast with the results for dose A with decreases of 2.8 and 1.8 per cent for the same intervals. Dose B thus gave a consistently stronger effect than was found with dose A. The effect of alcohol on the speed of finger movement with the typists is approximately of the same magnitude as that found on the speed of typewriting and in both cases represents a decrease in efficiency. The effect is in the same direction, but less than that found by Dodge and Benedict,[a] who report the average result for a finger-movement test of 6 seconds given in the same way as a change of 9 per cent.

Effect of Alcohol on Eye Movements.

As hinted in the description of the technique for this measurement (see p. 15), the two movements (adductive and abductive) are not of equal duration. For the right eye to execute a movement from the right-hand fixation mark to the left-hand mark (the adductive movement) requires a longer time by 10 or 15 per cent than to make the movement from the left-hand fixation mark to the right-hand mark (the abductive movement). The distance to be traversed is the same. Since there is this characteristic difference between the two movements, we have treated them here as two separate events and have tabulated the data separately.

Adductive Eye Movements.

Table 18 shows the individual averages for eye movement to the left. There is a surprisingly wide variation in the values for the different subjects, but the individual men on any one day are fairly consistent with themselves. The preliminary values for the three groups of days are not very far apart. For the normal days, the duration of the movement is 115.4 σ; for the days on which dose A was taken there is a similar value of 118.8 σ; and for the dose B day, it is 121.4 σ, or a change of about 5 per cent. Normally, the eye movement becomes slower as the experiment progresses and the data indicate that these movements are slowest in the sixth and seventh periods, with a change of about 20 per cent. When the experiments were performed in the evening the subjects probably became somewhat sleepy in the latter part of the session. By the method of preliminary differences, all the periods with dose A except the last (period 8) show longer duration required for the movement when these are compared with the normal values. The average for the seven periods following ingestion of dose A was +6.7 per cent. If the values in table 18 are directly contrasted, period for period, and the percentages determined, we find that all have a plus sign and average +8.8 per cent. Hence it may be considered that dose A for 4 hours after ingestion caused a decrease in the speed of the eye movement on the average of about 7.7 per cent. If we consider the experimental

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 244, table 46.

TABLE 18.—*Velocity of horizontal adductive eye movements.*

Subject, date, and type of experiment.	Eye movements (left) in 0.001 second at successive half-hour periods.							
	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
Control:	σ	σ	σ	σ	σ	σ	σ	σ
Lig, Sept. 30..........	90	90	94	93	89	87	97	93
Oct. 3..........	96	90	100	103	105	110	105	97
Roj (II), Oct. 5..........	130	147	152	144	149	150	162	151
Oct. 8..........	144	133	154	155	152	145	162	157
Suf, Nov. 4..........	100	110	114	110	122	114	116	116
Nov. 7..........	104	105	112	117	127	127	136	133
Fam (II), June 10..........	145	154	155	171	165	240	190	164
June 13..........	162	177	198	177	204	223	201	174
Mih (II), June 22..........	93	90	92	91	93	100	94	91
June 25..........	90	92	90	89	91	94	91	81
Averages (A)............	115.4	118.8	126.1	125.0	129.7	139.0	135.4	125.7
Differences (D)..........	....	+ 3.4	+10.7	+ 9.6	+14.3	+23.6	+20.0	+10.3
Alcohol, dose A:								
Lig, Oct. 1..........	91	98	104	99	96	92	96	96
Roj (II), Oct. 6..........	146	152	158	177	184	179	173	163
Suf, Nov. 5..........	116	140	140	144	144	149	148	127
Fam (II), June 11..........	153	183	170	196	185	278	230	163
Mih (II), June 23..........	88	96	87	93	88	88	84	94
Averages (A_1)............	118.8	133.8	131.8	141.8	139.4	157.2	146.2	128.6
Differences (D_1)..........	....	+15.0	+13.0	+23.0	+20.6	+38.4	+27.4	+ 9.8
Alcohol, dose B:								
Lig, Oct. 2..........	105	120	117	115	118	112	106	104
Roj (II), Oct. 7..........	137	155	152	172	186	218	204	171
Suf, Nov. 6..........	116	160	170	163	166	141	155	123
Fam (II), June 12..........	163	155	146	172	176	170	174	156
Mih (II), June 24..........	86	95	97	95	99	101	93	91
Averages (A_2)............	121.4	137.0	136.4	143.4	149.0	148.4	146.4	129.0
Differences (D_2)..........	....	+15.6	+15.0	+22.0	+27.6	+27.0	+25.0	+ 7.6
Effect of alcohol, dose A:								
Differences for group (D_1-D)	....	+11.6	+ 2.3	+13.4	+ 6.3	+14.8	+ 7.4	− 0.5
Contrast for group (A_1-A)..	....	+15.0	+ 5.7	+16.8	+ 9.7	+18.2	+10.8	+ 2.9
Per cent from differences....	....	+ 9.9	+ 2.0	+11.4	+ 5.4	+12.6	+ 6.3	− 0.4
Per cent from contrast......	....	+12.6	+ 4.5	+13.4	+ 7.5	+13.1	+ 8.0	+ 2.3
Effect of alcohol, dose B:								
Differences for group (D_2-D)	....	+12.2	+ 4.3	+12.4	+13.3	+ 3.4	+ 5.0	− 2.7
Contrast for group (A_2-A)..	....	+18.2	+10.3	+18.4	+19.3	+ 9.4	+11.0	+ 3.3
Per cent from differences....	....	+10.3	+ 3.6	+10.5	+11.2	+ 2.9	+ 4.2	− 2.3
Per cent from contrast......	....	+15.3	+ 8.2	+14.7	+14.9	+ 6.8	+ 8.1	+ 2.6

session in two parts, that is, determine the average for periods 2 to 5, we find by the difference method a decrease of 7.2 per cent, and by the contrast 9.5 per cent, or an average of 8.4 per cent. For periods 6 to 8, the difference method gives a decrease in speed of 6.2 per cent, the contrast method 7.8 per cent, with an average of 7.0 per cent. Thus there was a slightly more pronounced effect in the 2 hours succeeding ingestion.

For dose B the changes are likewise in the direction of a slower speed of movement. The difference method gives an average effect for the periods following the ingestion of the alcohol of 5.8 per cent and by the direct contrast method the effect seems to be 10.1 per cent. On the average, therefore, a change of approximately 8 per cent seems to have taken place as the result of the larger dose of alcohol. This is but slightly above that found for dose A. There is, however, a greater variation between the first and second two-hour periods than with dose A. In the first (the average for periods 2 to 5) the difference method gives an average effect of 8.9 per cent, the contrast method 13.3 per cent, and the average of the two methods 11.1 per cent. For the last 1½ hours (periods 6 to 8) the difference method gives 1.6 per cent, the contrast method 5.8 per cent, and the average of the two 3.7 per cent. The influence of the alcohol is to retard the adductive eye movements, and the intensity of the effect is about three times as strong in the first 2 hours after alcohol as in the second 2 hours.

Abductive Eye Movements.

The alcohol results are just as consistent for the eye movements to the right, but the effect is regularly smaller. (See table 19.) For dose A all periods show plus percentage changes, with an average decrease by the difference method of 4 per cent in the speed of the eye movement. For dose B, also, all of the periods have the same sign and give by the same method an average decrease in speed of 5.2 per cent. These figures approximate the average effect as computed by the contrast method, this being for dose A +4.7 per cent and for dose B +6.0 per cent. In both cases the averages are slightly larger than those found by the difference method. The group average after dose A for periods 2 to 5 by differences is 5.5 per cent, by contrast 6.3 per cent, with a combined average of 5.9 per cent. For periods 6 to 8, by the difference method it is 2.0 per cent, by the contrast method 2.7 per cent, with an average of 2.3 per cent. For dose B the average effect for periods 2 to 5 obtained by both methods is 7.4 per cent, while for periods 6 to 8 it is 3.3 per cent. There is a consistent difference in the size of the effect for doses A and B and in both instances, the first 2-hour period shows approximately twice as large an alcohol effect as is evident in the second 2-hour period.

For a general statement, the results obtained in the first 2-hour period with eye movement, left and right, may be averaged together. For dose A there is a consistent decrease in speed amounting to about 7 per cent, while for dose B there is an average decrease in speed during the 2 hours following ingestion of approximately 9 per cent. The eye movements were judged by Dodge and Benedict[a] to give the most characteristically trustworthy results for the effect of alcohol. The general average effect recorded here is considerably larger than that found for the same individuals in observations of finger movements or for the speed of typewriting, but not so large as was found for amplitude of the protective lid reflex, and especially for the errors in typewriting. This tends to indicate that eye movement stands intermediate between a simple speed of performance on the one side and an accuracy measurement on the other. In previous publications of results for the finger-movement and eye-movement tests, it is characteristic that the eye movement shows the larger effect. It is quite obvious that the eye movement contains a requirement for accuracy of adjustment which does not exist in the finger movement. Although in the data given here

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 265.

TABLE 19.—*Velocity of horizontal abductive eye movements.*

Subject, date, and type of experiment.	Eye movements (right) in 0.001 second at successive half-hour periods.							
	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
Control:	σ	σ	σ	σ	σ	σ	σ	σ
Lig, Sept. 30	90	83	86	83	84	82	94	89
Oct. 3	93	87	97	98	103	103	93	95
Roj (II), Oct. 5	116	127	117	114	116	112	126	114
Oct. 8	106	113	107	115	117	105	120	115
Suf, Nov. 4	87	95	90	93	97	89	97	97
Nov. 7	90	93	93	98	107	109	103	104
Fam (II), June 10	111	127	126	127	124	181	140	127
June 13	122	124	131	141	137	164	148	126
Mih (II), June 22	81	79	84	85	87	92	87	84
June 25	78	77	78	80	78	80	79	79
Averages (A)	97.4	100.5	100.9	103.4	105.0	111.7	108.7	103.0
Differences (D)	....	+ 3.1	+ 3.5	+ 6.0	+ 7.6	+14.3	+11.3	+ 5.6
Alcohol, dose A:								
Lig, Oct. 1	89	93	92	93	88	86	87	88
Roj (II), Oct. 6	112	120	131	130	141	141	131	122
Suf, Nov. 5	90	108	111	114	103	110	114	101
Fam (II), June 11	122	125	127	138	126	171	136	129
Mih (II), June 23	79	89	83	82	83	81	83	81
Averages (A_1)	98.4	107.0	108.8	111.4	108.2	117.8	110.2	104.2
Differences (D_1)	....	+ 8.6	+10.4	+13.0	+ 9.8	+19.4	+11.8	+ 5.8
Alcohol, dose B:								
Lig, Oct. 2	93	108	114	109	107	100	97	93
Roj (II), Oct. 7	104	109	128	120	139	139	161	134
Suf, Nov. 6	99	111	113	112	120	118	112	107
Fam (II), June 12	119	126	103	126	121	126	124	114
Mih (II), June 24	78	84	86	85	87	88	86	79
Averages (A_2)	98.6	107.6	108.8	110.4	114.8	114.2	116.0	105.4
Differences (D_2)	....	+ 9.0	+10.2	+11.8	+16.2	+15.6	+17.4	+ 6.8
Effect of alcohol, dose A:								
Differences for group (D_1-D)	....	+ 5.5	+ 6.9	+ 7.0	+ 2.2	+ 5.1	+ 0.5	+ 0.2
Contrast for group (A_1-A)	....	+ 6.5	+ 7.9	+ 8.0	+ 3.2	+ 6.1	+ 1.5	+ 1.2
Per cent from differences	....	+ 5.6	+ 7.1	+ 7.2	+ 2.2	+ 5.2	+ 0.5	+ 0.2
Per cent from contrast	....	+ 6.5	+ 7.8	+ 7.7	+ 3.0	+ 5.5	+ 1.4	+ 1.2
Effect of alcohol, dose B:								
Differences for group (D_2-D)	....	+ 5.9	+ 6.7	+ 5.8	+ 8.6	+ 1.3	+ 6.1	+ 1.2
Contrast for group (A_2-A)	....	+ 7.1	+ 7.9	+ 7.0	+ 9.8	+ 2.5	+ 7.3	+ 2.4
Per cent from differences	....	+ 6.0	+ 6.8	+ 5.9	+ 8.8	+ 1.3	+ 6.2	+ 1.2
Per cent from contrast	....	+ 7.1	+ 7.8	+ 6.8	+ 9.3	+ 2.2	+ 6.7	+ 2.3

no attention is paid to the amount of corrective movement which is required to bring the eye absolutely to the fixation point, still the factor of accuracy is playing a prominent rôle. When the eye is moved suddenly from one point to another in this test, the second point is seen by indirect vision, the distance has been estimated, and the coordination elaborated accordingly. The eye-movement test thus combines speed and accuracy, and as a neuromuscular process of fundamental importance to the efficiency of the individual is rather strongly depressed by such amounts of alcohol as have been used in these experiments. Considerably more eye-movement data are given in later chapters.

Effect of Alcohol on Word Reactions.

The word reaction, as measured according to the routine used in the Nutrition Laboratory, requires about 455 σ.[a] The technique employed is described on page 14. The comparable data for the five typists are given in table 20. For normal days the preliminary value is 466 σ. The averages for the reaction time after the control dose are always longer, rising to 495 σ; this represents a trifle over 6 per cent in range. The values for the preliminary periods for the group of days on which doses A and B were taken are very nearly the same as those for the normal days, but the periods following show lengthening up to 11 per cent, which is one way of indicating the effect of alcohol. By the method of preliminary differences the dose A values indicate a consistently slower reaction time in all periods following ingestion of the alcohol. The percentages of change are of about the same magnitude with which we have become familiar in previous measures, ranging from +1.7 to +6.2 per cent, the average for all periods following dose A being +4.3 per cent. By direct contrast of averages, period for period, we find also consistency in the direction of the sign. The average for periods 2 to 8 by contrast is +3.1 per cent; the combination result, therefore, is an average increase in reaction time, i. e., a slower reaction, of 3.7 per cent. The effect indicated in the first 2 hours is only slightly greater than in the subsequent 1½ hours. The average for periods 2 to 5 is, by differences, 4.6 per cent, and by contrast 3.4 per cent, with a combined average of 4.0 per cent. For periods 6 to 8 the difference method yields 3.9 per cent and the contrast 2.8 per cent with a combination average of 3.4 per cent.

Dose B for this measurement shows effects from the alcohol which were only a trifle larger than those found with dose A. The preliminary value for dose B, as previously noted, is within 1 per cent of that for the normal control dose. All periods, with the exception of No. 8, show plus signs in their expression of the effect of the alcohol. These values range for the difference method from −0.9 for period 8 to +8.4 for period 2. The average for all periods is +4.3 per cent, which is identical with that for dose A by the method of differences. When the effect of alcohol is computed by contrasting the averages, it is seen that all periods likewise have positive values, indicating a slower reaction, except in period 8, in which the effect is slightly negative. The average for all the periods is 3.4 per cent, which also is very nearly the average for the dose A days as found by the direct contrast method. The total average by both methods for the effect of dose B on the sessions following ingestion is 3.8 per cent, as compared with the similar average of 3.7 per cent, which was found with dose A. During the first two hours the combination effect for dose B was 5.1 per cent, while for periods 6 to 8 the effect was 2.3 per cent.[a] The stronger influence shortly after the ingestion of alcohol, while rather slight with dose A, was indicated with both doses; the difference between the two doses is not strongly reflected in the results obtained with this measurement.

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 106; see, also, Benedict Miles, Roth, and Smith, Carnegie Inst. Wash. Pub. No. 280, 1919, p. 603.

TABLE 20.—*Reaction time of five typists for speaking 4-letter words.*

Subject, date, and type of experiment.	Speed of word reactions in 0.001 second at successive half-hour periods.							
	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
Control:	σ	σ	σ	σ	σ	σ	σ	σ
Lig, Sept. 30	440	472	458	474	461	452	501	496
Oct. 3	472	476	526	511	489	503	487	488
Roj (II), Oct. 5	540	530	504	489	505	483	514	502
Oct. 8	454	455	455	491	473	454	470	466
Suf, Nov. 4	661	684	691	654	616	616	671	671
Nov. 7	536	554	545	507	563	550	560	628
Fam (II), June 10	402	430	405	426	413	412	416	420
June 13	340	370	394	369	366	392	407	417
Mih (II), June 22	402	417	416	425	419	437	437	444
June 25	409	409	396	401	417	427	417	413
Averages (A)	466	480	479	475	472	473	488	495
Differences (D)	....	+14	+13	+ 9	+ 6	+ 7	+22	+29
Alcohol, dose A:								
Lig, Oct. 1	453	489	489	459	510	456	451	507
Roj (II), Oct. 6	436	473	488	484	486	496	485	503
Suf, Nov. 5	616	613	622	572	612	675	658	660
Fam (II), June 11	386	447	440	477	402	429	430	448
Mih (II), June 23	416	455	456	443	442	431	431	421
Averages (A_1)	461	495	499	487	490	497	491	508
Differences (D_1)	....	+34	+38	+26	+29	+36	+30	+47
Alcohol, dose B:								
Lig, Oct. 2	484	563	521	508	497	505	509	520
Roj (II), Oct. 7	446	463	472	479	498	538	532	525
Suf, Nov. 6	562	702	639	623	614	608	702	602
Fam (II), June 12	404	410	405	436	427	395	366	377
Mih (II), June 24	416	439	421	425	422	411	413	409
Averages (A_2)	462	515	492	494	492	491	504	487
Differences (D_2)	....	+53	+30	+32	+30	+29	+42	+25
Effect of alcohol, dose A:								
Differences for group (D_1-D)	....	+20	+25	+17	+23	+29	+ 8	+18
Contrast for group (A_1-A)	....	+15	+20	+12	+18	+24	+ 3	+13
Per cent from differences	....	+ 4.3	+ 5.4	+ 3.7	+ 5.0	+ 6.2	+ 1.7	+ 3.9
Per cent from contrast	....	+ 3.1	+ 4.2	+ 2.5	+ 3.8	+ 5.1	+ 0.6	+ 2.6
Effect of alcohol, dose B:								
Differences for group (D_2-D)	....	+39	+17	+23	+24	+22	+20	− 4
Contrast for group (A_2-A)	....	+35	+13	+19	+20	+18	+16	− 8
Per cent from differences	....	+ 8.4	+ 3.7	+ 4.9	+ 5.2	+ 4.7	+ 4.3	− 0.9
Per cent from contrast	....	+ 7.3	+ 2.7	+ 4.0	+ 4.2	+ 3.8	+ 3.3	− 1.9

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[a] Dodge and Benedict averaged results for doses A and B in their data (see their table 46, p. 244) and found a slowing of 3 per cent in the word reactions after alcohol.

VARIABILITY OF WORD REACTIONS.

When reactions are taken by the technique used in these experiments, it is, of course, recognized that the voice key will not be opened so promptly by the initial sound of certain words as by others. From this cause alone there will naturally be a variation in the reaction time for different words as recorded on the kymograph drum. This factor, however, should not interfere with our making a comparison of the variation between different experimental periods, because the same set of words was always used for reaction purposes. Prior to each test the 24-word cards were thoroughly mixed, so that the subject could in no way anticipate the order of their exposure. The group of word sounds thus required for the 24-word reactions which made up the test, as given, was always the same, but in different order. The mean variation for these reactions to 4-letter word stimuli has been determined in each case and divided by the average reaction time for the particular period and subject. The resulting coefficients of variability have been tabulated like the data for the word-reaction time.

In the previous use of this measurement at the Nutrition Laboratory it has always been a matter of surprise that the variability was such a small percentage of the average reaction time. In the first report of such data,[a] Dodge and Benedict called attention to the fact that in their results the mean variation hardly reached 10 per cent of the average. In two other publications from the Nutrition Laboratory the writer has called attention to the same small coefficient of variability with the word reactions. In the intensive repetition experiment on one man[b] this coefficient was found to be 6.5 per cent of the average normal reaction time for this subject. In the large amount of data collected during the study of undernutrition,[c] the writer found (standard deviations were used in this case) the coefficient of variability for the individual series of reactions to range from 7 to 13 per cent of the reaction time.

The data presented in table 21 are much like the results previously obtained. The average for the preliminary period of the control days is 8.0 per cent, for the preliminary period of the days with dose A, 8.1 per cent, and for the days with dose B, 6.4 per cent. The direct comparison of the averages for periods following the control dose against periods following either dose A or dose B shows there is not a great change after the alcohol. However, the alcohol values tend to be the larger, especially in period 2, which, in this case, means about 25 minutes following the alcohol dose. After dose A the increase in the variability in period 2 amounts to 11.5 per cent. No change appears in periods 3 and 4, there is a slightly less variability (−3.7 per cent) in period 5, with an increase in variability of approximately 5 per cent in periods 6, 7, and 8. Following dose B there is, according to the contrast method, an increased variability of 34.6 per cent in period 2, but little change in periods 3, 4, and 5, with an increase again in periods 6 and 7, but almost no change in period 8. By the method of differences, the percentage effects with dose A are roughly the same as with the contrast method, but are much larger with dose B, since the preliminary normal for dose B is considerably below the other preliminary normals. There is some reason to suppose that this low preliminary average for dose B is not entirely trustworthy, and accordingly it is preferable to compute the effects by the contrast method.

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 107.

[b] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 62.

[c] Benedict, Miles, Roth, and Smith, Carnegie Inst. Wash. Pub. No. 280, 1919, p. 603.

TABLE 21.—*Percentage variability in the reaction time for speaking 4-letter words.*

Subject, date, and type of experiment.	Variability in the speed of reaction at successive half-hour periods.							
	Prelim.	Following dose.						
	1	2	3	4	5	6	7	8
	p. ct.	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*
Control:								
Lig, Sept. 30	5.7	6.6	5.9	5.7	6.5	6.4	7.0	7.7
Oct. 3	6.8	6.1	11.0	9.8	8.2	8.2	7.0	10.7
Roj (II), Oct. 5	11.9	5.7	9.5	8.4	10.3	6.2	8.2	6.8
Oct. 8	8.2	7.3	8.4	8.6	8.9	7.3	7.7	6.4
Suf, Nov. 4	14.5	19.2	17.2	12.7	10.6	14.8	15.1	15.1
Nov. 7	9.3	8.7	8.8	5.5	11.0	12.9	13.2	14.7
Fam (II), June 10	6.0	7.9	8.4	6.3	8.5	7.8	5.5	6.4
June 13	8.5	6.8	4.6	9.8	7.7	6.4	8.6	8.9
Mih (II), June 22	4.7	5.5	4.1	5.4	5.3	4.8	4.1	4.3
June 25	4.2	3.9	3.5	3.2	5.3	8.2	5.0	5.3
Averages (A)	8.0	7.8	8.1	7.5	8.2	8.3	8.1	8.6
Differences (D)	......	− 0.2	+ 0.1	− 0.5	+ 0.2	+ 0.3	+ 0.1	+ 0.6
Alcohol, dose A:								
Lig, Oct. 1	5.3	10.0	8.2	5.9	9.2	6.4	10.9	12.0
Roj (II), Oct. 6	8.0	4.4	6.8	8.9	6.8	8.9	7.4	8.6
Suf, Nov. 5	17.5	16.5	10.9	8.9	11.6	16.5	14.6	14.1
Fam (II), June 11	4.4	6.5	8.4	8.2	7.2	6.8	6.7	6.0
Mih (II), June 23	5.3	6.2	6.1	5.4	4.8	5.1	3.7	4.3
Averages (A_1)	8.1	8.7	8.1	7.5	7.9	8.7	8.7	9.0
Differences (D_1)	......	+ 0.6	± 0.0	− 0.6	− 0.2	+ 0.6	+ 0.6	+ 0.9
Alcohol, dose B:								
Lig, Oct. 2	6.6	11.0	7.5	6.5	7.2	10.3	7.5	9.6
Roj (II), Oct. 7	4.7	5.6	5.9	6.9	6.8	13.8	10.5	9.7
Suf, Nov. 6	10.9	21.1	11.3	14.1	12.2	11.5	14.0	9.8
Fam (II), June 12	5.2	7.1	8.6	6.7	7.5	6.3	6.8	9.3
Mih (II), June 24	4.6	7.5	7.1	4.9	4.5	4.9	4.4	4.2
Averages (A_2)	6.4	10.5	8.1	7.8	7.6	9.4	8.6	8.5
Differences (D_2)	......	+ 4.1	+ 1.7	+ 1.4	+ 1.2	+ 3.0	+ 2.2	+ 2.1
Effect of alcohol, dose A:								
Differences for group (D_1-D)	......	+ 0.8	− 0.1	− 0.1	− 0.4	+ 0.3	+ 0.5	+ 0.3
Contrast for group (A_1-A)	......	+ 0.9	± 0.0	± 0.0	− 0.3	+ 0.4	+ 0.6	+ 0.4
Per cent from differences	......	+ 9.9	− 1.2	− 1.2	− 4.9	+ 3.7	+ 6.2	+ 3.7
Per cent from contrast	......	+11.5	± 0.0	± 0.0	− 3.7	+ 4.8	+ 7.4	+ 4.7
Effect of alcohol, dose B:								
Differences for group (D_2-D)	......	+ 4.3	+ 1.6	+ 1.9	+ 1.0	+ 2.7	+ 2.1	+ 1.5
Contrast for group (A_2-A)	......	+ 2.7	± 0.0	+ 0.3	− 0.6	+ 1.1	+ 0.5	− 0.1
Per cent from differences	......	+59.7	+22.2	+26.4	+13.9	+37.5	+29.2	+20.8
Per cent from contrast	......	+34.6	± 0.0	+ 4.0	− 7.3	+13.3	+ 6.2	− 1.2

It thus appears that the variability of the reaction time is influenced in the direction of an increase by the taking of the alcohol. This, of course, is not a new finding. It has been shown in each case in our previous publications and also in the previous discussion of the speed of typewriting. (See p. 59.) It is unknown why the effect was pronounced with both doses 25 minutes after the alcohol was taken, then practically disappeared for an hour and a half, after which it appeared quite distinctly again. The effect of alcohol on the word-reaction time does not disappear during this interval when, as has been seen with the typewriting and other measurements, the effects are usually at their maximum.

Summary for Effect of Alcohol on Typewriting Efficiency and Simpler Related Acts.

Without exception all of the measurements which have been used in these experiments with alcohol on typewriting and simpler related processes show a positive effect of the alcohol, and in each case this is interpreted to be in the direction of depression or decreased efficiency. This decrease has been indicated by both methods of computing the effect. These two methods of computation have been used not for the purpose of forcing an effect out of the data, but in an effort to view the results from every reasonable angle of approach, and to obtain the most trustworthy and conservative statement for the size of the alcohol effect as exhibited in the measurements used. In some cases the percentage effect has been larger by one method than by the other. Theoretically, the method of percentile differences should give the most logical and exact expression for the influence of the alcohol factor. Since, however, only one half-hour preliminary period was used in these experiments (and there are influences which tend to make the performance in the preliminary period variable from day to day as a result of extraneous factors which are practically beyond control), a direct comparison of periods which followed the alcohol dose with periods which followed the control dose has also been used in the series of experiments reported in this chapter.

A summary for the effect of alcohol on efficiency in typewriting and for the other measurements is given in table 22. This table presents only average results for the percentage effect in the various periods following the ingestion of the alcohol. In each instance the percentage represents the average of the results obtained by the two methods of computation, i. e., from differences and from contrast. The results for the three typewriting tests (practice copy, sense copy, and nonsense copy) are grouped in one average. The typewriting tests required about half of each experimental period, hence these data represent a considerably larger amount of material than that for any other measurement given in the table. The various measurements are indicated at the left of the table and the results are given separately for doses A and B. The algebraic signs must be considered in the light of their origin and of the particular test. A plus sign in relation to increase of errors after alcohol and a minus sign in relation to speed (indicating a slower speed) obviously do not conflict, but both indicate a decrease in typewriting efficiency. Usually within one horizontal line of percentages the algebraic sign is predominantly minus or plus. In fact, 12 of the 20 lines in the table show no reversal of sign, but are always in the same direction from periods 2 to 8; several others have but one reverse sign, this usually occurring in periods 6, 7, or 8 or in period 2, the first test after the taking of the alcohol. There is a well-defined tendency for the alcohol effect to be strongest in the hour or two following ingestion, with the maximum effect in periods 3 or 4.

The typical effect of alcohol on the speed of neuro-muscular processes is not so large as the effect upon the accuracy of the processes, particularly as represented in the typewriting performance. If the results are summarized, as in table 23, by grouping periods 2 to 5 for purposes of averaging and also periods 6 to 8, the variation in the alcohol effect on the different measurements may be most clearly seen. In the first 2 hours following alcohol, the effect on the typewriting errors is considerably larger than on any other measurement, being +39.3 and +72.4 per cent for doses A and B, respectively. In the second 2 hours, periods 6 to 8, dose A produces an increase in error of +14.5 per cent, while dose B increases the errors +35.1 per cent. Next in the order of magnitude of alcohol effect in table 23 is the

TABLE 22.—*Summary of effect of alcohol on efficiency in typewriting and in simpler related acts.*[1]

Measurement and dosage.	Progressive alcohol effect at half-hour intervals following dose.						
	2	3	4	5	6	7	8
Typewriting:[2]	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*
Errors:							
Dose A	+25.0	+64.4	+37.2	+30.8	+37.6	− 6.2	+12.2
Dose B	+46.1	+103.1	+88.4	+52.2	+44.8	+32.3	+28.2
Speed:							
Dose A	− 0.7	− 3.1	− 2.6	− 3.6	+ 0.5	− 0.9	− 0.4
Dose B	− 3.8	− 5.4	− 3.6	− 2.9	+ 0.3	− 1.7	+ 1.7
Heart-cycle duration:[3]							
Dose A	− 1.6	− 6.3	− 9.3	− 5.1	−10.6	− 6.3	− 4.7
Dose B	− 5.7	− 9.0	− 9.2	− 8.3	−11.1	−10.2	− 6.2
Lid reflex:							
Latency:							
Dose A	− 2.7	+ 2.7	+ 8.1	+ 8.2	+24.9	± 0.0	+ 8.1
Dose B	+ 9.5	− 1.3	+ 4.1	+ 9.6	+12.5	+ 4.1	+ 6.8
Amplitude:							
Dose A	−32.8	+26.4	−23.3	− 5.5	−42.0	−25.5	−10.0
Dose B	−62.3	− 1.1	−21.3	−25.5	−32.2	−16.1	−25.6
Finger-movement speed:							
Dose A	− 4.7	− 1.7	− 1.7	− 3.0	− 1.2	− 2.6	− 1.7
Dose B	− 5.1	− 0.7	− 3.6	− 5.4	− 2.8	− 2.1	− 3.5
Eye movements:							
Adductive:							
Dose A	+11.3	+ 3.3	+12.4	+ 6.5	+12.9	+ 7.2	+ 1.0
Dose B	+12.8	+ 5.9	+12.6	+13.1	+ 4.9	+ 6.2	+ 0.2
Abductive:							
Dose A	+ 6.1	+ 7.5	+ 7.5	+ 2.6	+ 5.4	+ 1.0	+ 0.7
Dose B	+ 6.6	+ 7.3	+ 6.4	+ 9.1	+ 1.8	+ 6.5	+ 1.8
Word reactions:							
Speed:							
Dose A	+ 3.7	+ 4.8	+ 3.1	+ 4.4	+ 5.7	+ 1.2	+ 3.3
Dose B	+ 7.9	+ 3.2	+ 4.5	+ 4.7	+ 4.3	+ 3.8	− 1.3
Variability:							
Dose A	+10.7	− 0.6	− 0.6	− 4.3	+ 4.3	+ 6.8	+ 4.2
Dose B	+47.2	+11.1	+15.2	+ 3.3	+25.4	+17.7	+ 9.8

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[1] All of the results given in the table are averages from the two methods of calculation, per cent from differences and per cent from contrast.

[2] The alcohol effect on typewriting is the average of the results for practice, sense, and nonsense writing tasks.

[3] The results for the three groups of heart-rate data are averaged for these values.

amplitude of the lid reflex, which is decreased 8.8 per cent and 27.5 per cent for doses A and B, periods 2 to 5, and 25.8 per cent and 13.9 per cent for doses A and B, periods 6 to 8. The large alcohol effect on the amplitude of lid reflexes has been noted in former publications from the Nutrition Laboratory.[a]

The alcohol effect on the eye movements is fairly large and quite consistent and stands in magnitude between that for the errors in typewriting and such measurements as speed of typewriting, speed of finger movement, latency of lid reflex, and speed of the word reaction—effects which range from about 2.5 to 4 per cent for dose A and from 4 to about 6 per cent for dose B as an average for periods 2 to 5. The effect upon the heart-rate (shortened length of pulse-cycle) is about the same magnitude as that upon the horizontal eye movement, but is peculiar in that it is definitely larger for both doses in the second 2-hour period after alcohol. There is a tendency toward this delayed effect also in the data for the lid reflex.

TABLE 23.—*Group summary of effect of alcohol on efficiency in typewriting and in simpler related acts.*[1]

Measurements.	Periods 2 to 5, 0 to 2 hrs. after alcohol.		Periods 6 to 8, 2 to 3½ hrs. after alcohol.	
	Dose A.	Dose B.	Dose A.	Dose B.
Typewriting:[2]	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*
Errors	+39.3	+72.4	+14.5	+35.1
Speed	− 2.5	− 3.9	− 0.3	+ 0.1
Heart-rate:[3]				
Cycle duration	− 5.6	− 8.1	− 7.2	− 9.2
Lid reflex:				
Latency	+ 4.1	+ 5.5	+11.0	+ 7.8
Amplitude	− 8.8	−27.5	−25.8	−13.9
Finger-movement speed	− 2.8	− 3.7	− 1.8	− 2.8
Eye movements:				
Adductive	+ 8.4	+11.1	+ 7.0	+ 3.7
Abductive	+ 5.9	+ 7.4	+ 2.3	+ 3.3
Word reactions:				
Speed	+ 4.0	+ 5.1	+ 3.4	+ 2.3
Variability	+ 1.4	+19.2	+ 5.1	+17.7

[1] All of these percentage effects are averages from the two methods of calculation, i. e., per cent from differences and per cent from contrast.

[2] The results given for typewriting are the averages of the alcohol effects found with practice, sense, and nonsense tasks.

[3] The effects of alcohol on heart-rate during rest, work, and recuperation after typewriting are averaged for these values.

From this series of typewriting experiments we may draw the following conclusions:

(1) The alcohol effect demonstrated is more prominent after the ingestion of dose B (32 to 42 grams of alcohol diluted to 151 to 201 c. c. of fluid) than after the ingestion of dose A (21 to 28 grams of alcohol diluted to 108 to 200 c. c. of liquid).

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 71. Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 52.

(2) The changes produced by the alcohol in the processes measured are all concordant and in the direction of depression and decreased efficiency.

(3) The effect of the alcohol reaches its maximum with most of the measurements in periods 3 and 4, that is, from 30 minutes to 1½ hours after the complete ingestion of the dose. When periods are averaged so as to compare the effect in the first 2 hours with that found in the second 2 hours after ingestion, with but two exceptions (the heart-rate and the lid reflex) the effect is strongest in the first 2 hours.

(4) The accuracy of the typewriting is decreased very prominently, as shown by increase in the number of errors made, which, upon analysis, are found to be errors of such a grave nature as to reduce greatly the legibility of the typewritten copy. The efficiency is likewise reduced by a slight slowing of speed, as well as by an increase in the variability of the speed of typewriting.

(5) The heart-rate is increased from 5 to 7 per cent by dose A and from 8 to 9 per cent by dose B.

(6) The lid-reflex latency is lengthened definitely and the amplitude is decreased prominently by both doses.

(7) The finger-movement speed, like the speed of typewriting, is changed by only a small percentage, but in the direction of slower movement.

(8) The velocity of horizontal eye movement is reduced 7 per cent on the average by dose A and 9 per cent by dose B in the two hours after alcohol. The slowing in the speed of eye movement continued up to the end of the experiment.

(9) The word reactions are slower by 4 to 5 per cent for the two doses and show more variability in speed after the alcohol.

The five typists whom we have measured in this series of experiments were not selected for the purpose of proving any feature in reference to the effect of alcohol. The men were not picked from a large group but were taken as they came or as one subject would find another and introduce him. The only consideration was that they should be good typists. No reason can be assigned why these young men may not be considered as an average group, and the results of these experiments are believed to be representative of such as would be obtained from other groups of cooperative moderate drinkers. It is possible that if these same typists had ingested like amounts of alcohol in connection with their usual occupation, their typewriting of business letters or similar material would not have exhibited the same high degree of inaccuracy as appears in their laboratory work, for they might have noticed and corrected many of their errors and they probably would have had less tendency to write at maximum speed. At least it is evident from their subjective impressions (see Appendix, pages 277 to 283) that in most cases they would recognize by characteristic symptoms that alcohol had been taken and, if they observed closely, would be aware of the probable effects.

In their respective office positions, the decreased productiveness of the men might easily have escaped detection. Undoubtedly there are differences between the regular office performance and the laboratory test performance (further light on this problem will appear in the next chapter), but the course of the effect of alcohol observed in the Laboratory experiments must necessarily apply to the work of the office. Even a small percentage of increase in uncorrected errors in business correspondence is a matter of importance. In absence of proof to the contrary, it must be assumed that the average typist, as a result of taking such quantities of alcohol as were ingested on a comparatively empty stomach, will tend, in the hour or two following such a drink, to make from 25 to 50 per cent more errors in his work than if he had taken an equal volume of water.

CHAPTER III.

INFLUENCE OF REPETITION AND OF FOOD ON ALCOHOL EFFECT.

The importance of repeating series of alcohol experiments on the same individual has been emphasized in an earlier report.[a] The second series will unavoidably become more of a routine and thus occupy a different position on the learning curve. A subject in repeating the experiment may take a different attitude toward his work or may be in a somewhat changed physical condition. With alcohol there is a possible difficulty in the factor of the development of tolerance which conceivably may disturb the uniformity of results. Notwithstanding these and other factors which operate to make successive sets of results differ from each other, the experimental arrangement should be such that the results in one series will be confirmed, at least in direction, by results from further series of the same kind of experiments with the same subject. Unless this is the case, it is doubtful if that particular experimental program can very profitably be employed in testing a group of subjects.

INFLUENCE OF REPETITION ON EFFECT OF ALCOHOL IN EXPERIMENTS OF DIFFERENT LENGTH WITH ROJ.

Repetition experiments were made with the subject *Roj* to ascertain if two sets of results secured under like conditions were substantially in agreement with each other. An opportunity was desired to observe directly the difference between 3-hour and 5-hour experiments, and to find if there was much learning of the tests or tolerance acquired for the alcohol.

As will be seen from chronological table 1, page 33, *Roj* was the first subject to serve in the alcohol typewriting experiments. He came in the morning about 9 o'clock and in the first series continued the work until 12 o'clock. Breakfast of the usual amount had been taken at a seasonable hour previous to his coming to the Laboratory, so that approximately 3 hours elapsed between the taking of the food and the taking of the alcohol. After the first two days, which were used only as practice days for adapting the subject to the routine, *Roj* completed five experimental periods on each of the following four days, having thus a preliminary control period before the ingestion of the beverage and four regular 30-minute periods after the dose. This series was finished on September 26; the subject began his second series on October 5. In the second series he came to the Laboratory about 45 minutes earlier in the morning, but ate his breakfast at the same time as previously, so that the food was separated from the alcohol by about 2 hours. A practice day was not used in the second series; this was a mistake. On the first day of this second series, October 5, *Roj* completed only 8 periods, that is, 7 following the taking of the control dose. On the other three days he completed 10 periods in the same time. In previous tables we have given only the results for 8 periods, as the data were too fragmentary for averaging beyond the eighth period. In the comparison of the results of the two series with *Roj*, the data for all the periods will be given, but it should be noted that in series II there is but one normal day with periods 9 and 10, and it has been necessary to employ this in place of the usual average for the two normal days. The experimental procedures for the two series on *Roj* were identical, except in the matter of prolonging the experiment. The subject used the same typewriter, wrote the same practice sentence, the same sheets of scientific prose copy, and copied the same sets of nonsense 5-letter combinations, as well as performed the other tests which were employed in his first series. During the week intervening between the two sets, he had been on vacation and had not used a typewriter.

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[a] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 8.

TABLE 24.—*Influence of routine on alcohol effect in two series of experiments with Roj as indicated by percentage change after alcohol in errors of typewriting.*[1]

Typewriting material, series, and dose.	Percentage change in errors for periods after dose.								
	2	3	4	5	6	7	8	9	10
Practice:									
Roj I A	+34.6	+ 76.9	+ 15.8	+ 50.3	......	......	......	......	......
Roj II A	−33.4	+145.1	+ 27.6	+105.7	+ 60.9	− 48.4	+ 15.9	+ 5.6	+ 23.5
Roj I B	−10.5	+ 69.7	+ 48.8	+ 72.7	......	......	......	......	......
Roj II B	−11.5	+139.4	+153.6	+177.9	+177.9	+116.4	+ 51.9	+ 78.5	+ 77.2
Prose:									
Roj I A	−14.9	− 14.6	− 36.1	− 10.0	......	......	......	......	......
Roj II A	+74.4	+ 83.4	+137.9	+ 55.5	+ 88.6	+102.5	+ 28.5	+113.7	+ 28.7
Roj I B	+37.2	+ 47.1	+ 61.5	+ 82.8	......	......	......	......	......
Roj II B	+24.3	+ 68.8	+ 90.1	+153.4	+ 88.3	+115.4	+116.6	+225.5	+112.5
Nonsense:									
Roj I A	+56.6	− 3.3	+ 41.3	+ 13.2	......	......	......	......	......
Roj II A	+39.5	+ 52.0	+ 59.8	+ 0.6	+ 63.4	+ 44.9	+ 36.1	+ 3.5	+ 50.0
Roj I B	−11.9	− 20.9	+ 38.1	+ 15.2	......	......	......	......	......
Roj II B	+35.6	+ 54.9	+125.8	+ 34.8	+139.0	+105.9	+ 27.2	+ 66.7	+ 66.1
Average:									
Roj I A	+25.4	+ 19.7	+ 7.0	+ 17.8	......	......	......	......	......
Roj II A	+26.8	+ 93.5	+ 75.1	+ 53.9	+ 71.0	+ 33.0	+ 26.8	+ 40.9	+ 34.1
Roj I B	+ 4.9	+ 32.0	+ 49.5	+ 56.9	......	......	......	......	......
Roj II B	+16.1	+ 87.7	+123.2	+122.0	+135.1	+112.6	+ 65.2	+123.6	+ 85.3

[1] In this table and in tables 25, 26, 28, and 29 the percentages represent the averages obtained by the difference and contrast methods. (See p. 46.)

Our comparison of series I and II with *Roj* need not be carried through all of the different measurements which were made. It will be sufficient to give summary tables for the chief feature of the experiment, that is, the typewriting tests. In computing the effect of the alcohol, both methods have been used, that is, the percentages of change have been obtained (1) on the basis of differences by employing the preliminary values, and (2) by direct comparison of the control and alcohol periods, or what we have called the "contrast method." The percentage results given in table 24 are in each case an average of the results obtained by the two methods of computation for the percentage of errors made in the different kinds of typewriting. In the left-hand column of the table we indicate the nature of the test, i. e., practice, sense prose, and nonsense typewriting. The final average results are given separately in each case for the two series of experiments and for the two doses of alcohol (dose A and dose B) for the periods following the dose. As explained previously, there were four 30-minute periods following the dose in series I and the whole experiment continued about 3 hours. In series II, there were nine 30-minute periods following the dose of alcohol, and the whole experiment continued about 5 hours. The data for the first 8 periods of the second series (*Roj* II) have been included in previous tables giving the results for the whole group of typists. The results for series I do not appear elsewhere, and, as close inspection reveals no peculiarities in the data, they are given here in summary form only.

Most of the values in table 24 are positive, indicating an increase in errors of typewriting as a result of the alcohol. When minus values occur they are usually not so large as the plus values. As was found in the data for the whole group of typists, the effect of the alcohol with *Roj* is to increase considerably the percentage of error in typewriting. If the values in each pair of lines for series I and series II (periods 2 to 5, inclusive) are compared, it will be noted that the larger alcohol effect usually appears in series II. If the results for all three kinds of typewriting tests are averaged, as at the bottom of this table, it is found that in series I with dose A there are increases in error of 25.4, 19.7, 7.0, and 17.8 per cent for periods 2 to 5, while the parallel values for series II with the same dose are 26.8, 93.5, 75.1, and 53.9 per cent. With dose B, series I, we find increases in error of 4.9, 32.0, 49.5, and 56.9 per cent, while series II shows increases for the same periods of 16.1, 87.7, 123.2, and 122.0 per cent. The two series therefore agree as to the direction of the effect of alcohol on the percentage of typewriting errors with this subject, but the effect in the second series is conspicuously larger with both doses.

A further consideration of the results with *Roj* may be made by noting the effect upon the speed of typewriting as represented in the number of strokes per second. The average percentages of change in the speed of writing for the different tasks are given in table 25 for the two alcohol doses and the two series of experiments. It should be recalled that a minus sign indicates a slower rate of typewriting. As was previously found for the whole group of typists, the percentage effect of alcohol shown in table 25 upon the number of strokes per second is quite small, ranging usually between 2 and 5 per cent. The ratio of minus signs to plus signs is 2 to 1 in that portion of the table represented by periods 2, 3, 4, and 5. Naturally, when the changes are small, they will not be so uniformly in the same direction. Comparing the general averages for the two series of experiments with *Roj* after dose A, we find but little difference. Series I gives averages of −0.5, −2.0, −3.0, and −1.5 per cent in periods 2 to 5, while series II shows +1.2, −2.4, −2.6, and −3.9 per cent in the corresponding periods. In the two series with dose B, the alcohol effect appears to be less in the second, the averages for series II being −1.4, +0.5 −1.9, and +1.0 as compared to +3.7, −3.5, −2.2, and −3.8 per cent for series I.

As previously explained, the experimental day in the second series was 2 hours longer than in the first series, and thus gave results for 5 additional periods. Examination of table 24 (p. 97) shows that these results, which represent the periods in the interval of 2 to 4½ hours after the ingestion of the alcohol, are all positive, with the single exception of period 7, dose A, with the practice sentence. Most of these values are of fairly large denomination and force one to conclude, especially for periods 6, 7, and 8, for which the data are more nearly complete, that the alcohol effect is still prominently present at this time. Unfortunately, the data for periods 9 and 10 have but one normal day for comparison, and probably a part of the eccentricity of these percentages is to be explained by this circumstance. It seems conclusive, however, that the experiments were not prolonged sufficiently to show a great reduction in the alcohol effect as expressed in the tendency toward increase in typewriting errors.

TABLE 25.—*Influence of routine on alcohol effect in two series of experiments with Roj as indicated by percentage change after alcohol in strokes per second in typewriting.*

Typewriting material, series, and dose.	Percentage change in number of strokes for periods after dose.								
	2	3	4	5	6	7	8	9	10
Practice:									
Roj I A...	−1.6	−3.2	−1.6	−3.2	....	....	....	....	....
Roj II A...	+1.7	−1.6	+0.1	−4.9	+1.6	−6.3	+3.2	+1.6	+1.6
Roj I B...	+6.6	−3.3	−5.0	−8.1	....	....	....	....	....
Roj II B...	+0.1	−1.6	−6.3	+1.7	+0.1	−3.1	+1.6	+1.7	+9.7
Prose:									
Roj I A...	+1.0	−2.9	−1.0	−4.8	....	....	....	....	....
Roj II A...	+1.8	−0.1	−3.8	−5.6	−0.2	−1.9	−0.1	−5.6	+1.8
Roj I B...	+5.7	−1.9	−1.9	−3.8	....	....	....	....	....
Roj II B...	+0.9	+0.9	−2.9	−1.0	+6.7	+2.8	+4.7	+0.9	+2.8
Nonsense:									
Roj I A...	−0.9	+0.2	−6.5	+3.6	....	....	....	....	....
Roj II A...	±0.0	−5.4	−4.0	−1.3	−1.8	−3.4	−0.4	−1.1	−9.9
Roj I B...	−1.2	−5.4	+0.3	+0.4	....	....	....	....	....
Roj II B...	−5.1	+2.2	+3.5	+2.2	+3.2	−6.6	+3.3	+5.7	−1.8
Average:									
Roj I A...	−0.5	−2.0	−3.0	−1.5	....	....	....	....	....
Roj II A...	+1.2	−2.4	−2.6	−3.9	−0.1	−3.9	+0.9	−1.7	−2.2
Roj I B...	+3.7	−3.5	−2.2	−3.8	....	....	....	....	....
Roj II B...	−1.4	+0.5	−1.9	+1.0	+3.3	−2.3	+3.2	+2.8	+3.6

In the portion of table 25 represented by periods 6 to 10, plus signs are very slightly predominant, indicating a tendency to a faster speed in typewriting than had been obtained in the previous 2 hours. Hence the effect of alcohol on the speed of typewriting nearly disappears during this period of 2 to 4½ hours after the taking of the dose. The tendency to write a little faster at this time very likely accounts in part for continuation of the rather high percentages of error in the same time interval in table 24.

The results of this comparison between two successive sets of typewriting experiments on the same subject and for factors of both accuracy and speed of typewriting are summarized in table 26. For simplified comparison, the percentage effects of alcohol have been grouped into the first and second 2-hour periods by averaging the results of periods 2 to 5 and those for periods 6 to 8. The three kinds of typewriting tests, as well as the experimental series, are indicated in the column at the left. Among

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the results which represent periods 2 to 5, there are two exceptions to the general tendency. For percentage of errors, all are plus excepting sense prose in series I, with dose A. For the speed of typewriting, all values are minus, indicating slower speed, with the exception of the average for nonsense in series II, with dose B. The table itself is the simplest possible comparison for the three kinds of typewriting. The averages shown at the bottom in round numbers provide the following general results: Series I, dose A, periods 2 to 5, increase in errors, 18 per cent, decrease in speed, 2 per cent. For the same periods in series II, the increase in errors is 62 per cent and the decrease in speed is 2 per cent. For the first 2 hours after dose B, series I shows an increase in errors of 36 per cent and a decrease in speed of 2 per cent. For series II with the same dose there is an increase in errors of 87 per cent and a decrease in speed of about 1 per cent.

TABLE 26.—*Comparison of effect of alcohol in first and second 2-hour periods in two series of typewriting experiments with Roj.*

Typewriting material and series.	Percentage change in periods 2 to 5.				Percentage change in periods 6 to 8.			
	Dose A.		Dose B.		Dose A.		Dose B.	
	Errors.	Speed.	Errors.	Speed.	Errors.	Speed.	Errors.	Speed.
Practice:								
Roj I	+44.4	−2.5	+ 45.2	−2.5	....	....	....	....
Roj II	+61.3	−1.2	+114.9	−1.6	+ 9.5	−0.5	+115.4	−0.5
Prose:								
Roj I	−18.9	−2.0	+ 57.2	− .4	....	....	....	....
Roj II	+87.8	−1.9	+ 84.2	− .5	+73.2	− .7	+106.8	+4.7
Nonsense:								
Roj I	+27.0	− .9	+ 5.2	−1.5	....	....	....	....
Roj II	+38.0	−2.7	+ 62.8	+ .7	+48.1	−1.9	+ 90.7	− .1
Average:								
Roj I	+18	−2	+ 36	−2	....	....	....	....
Roj II	+62	−2	+ 87	−1	+44	−1	+104	+1

From these data it is seen that in the second series the effect of the alcohol was much more prominent, as indicated by the increase in typewriting errors. An examination of the data for the two sets of normal days of the two experimental series (see table 27) reveals a condition which has a bearing on this increase of errors. The two normal days of series I show average percentages for typewriting errors in periods 1 to 5 as follows: 2.2, 2.7, 3.2, 3.2, and 3.2 per cent. The similar averages for normal days of series II are 3.2, 3.1, 3.7, 3.3, and 3.5 per cent, and for periods 6 to 10, inclusive, 3.4, 3.7, 4.2, 3.6, and 3.1 per cent. The average number of strokes per second for the three kinds of typewriting tests in series I are 4.6, 4.7, 4.8, 4.7, and 4.8 for periods 1 to 5. The similar averages for series II are 5.1, 5.0, 4.9, 4.9, and 4.8 strokes per second, while those for periods 6 to 10 are 4.7, 4.8, 4.7, 4.7, and 4.8 strokes per second.

From this comparison of the performance levels for the two groups of control days, it is evident that in the second series of experiments, the subject wrote at faster speed and made normally a larger number of errors.

There is no alternative but to assume that this tendency was likewise operative in the alcohol days, with the result that the effect of the alcohol on the accuracy of the typewriting appeared larger in the second series.

The repetition experiments made with Subject VI[a] in an earlier research verify the direction of the former results obtained on this man by previous experimenters (Dodge and Benedict)[b] with the same apparatus and, in general, with the same experimental procedure. The second series with Subject VI showed a somewhat stronger and clearer alcohol effect. The results for the repetition experiments on *Roj* presented in the preceding pages are in agreement with those for Subject VI in earlier publications, that is, *Roj* I and *Roj* II confirm each other as to the nature of the alcohol effect found and show a somewhat clearer or larger change due to the beverage in the second series of experiments. Any developing tolerance for alcohol in these cases has not been sufficient to reverse this order and cause a decrease in the influence of alcohol in the later tests.

TABLE 27.—*Results of typewriting experiments with Roj on normal days.*

Typewriting material and series.	Prelim.	Periods after control dose.								
	1	2	3	4	5	6	7	8	9	10
Errors (p. ct.):										
Roj I:										
Practice	1.7	2.4	2.6	2.8	3.2	.....	.....	.....	.....	.....
Prose	1.8	2.1	2.4	2.7	2.1	.....	.....	.....	.....	.....
Nonsense	3.2	3.5	4.6	4.2	4.3	.....	.....	.....	.....	.....
Average	**2.2**	**2.7**	**3.2**	**3.2**	**3.2**	.....	.....	.....	.....	.....
Roj II:										
Practice	2.5	4.0	4.1	3.1	3.4	3.4	4.5	4.7	4.3	3.3
Prose	2.7	1.8	2.4	3.3	2.5	3.5	2.0	2.5	1.7	2.3
Nonsense	4.4	3.6	4.6	3.4	4.5	3.3	4.5	5.5	4.8	3.7
Average	**3.2**	**3.1**	**3.7**	**3.3**	**3.5**	**3.4**	**3.7**	**4.2**	**3.6**	**3.1**
Strokes per sec.:										
Roj I:										
Practice	5.9	6.2	6.4	6.2	6.4	.....	.....	.....	.....	.....
Prose	5.3	5.2	5.3	5.3	5.3	.....	.....	.....	.....	.....
Nonsense	2.7	2.8	2.7	2.7	2.7	.....	.....	.....	.....	.....
Average	**4.6**	**4.7**	**4.8**	**4.7**	**4.8**	.....	.....	.....	.....	.....
Roj II:										
Practice	6.5	6.5	6.3	6.4	6.2	6.4	6.4	6.1	6.2	6.2
Prose	5.6	5.5	5.4	5.2	5.3	4.8	5.2	5.1	5.3	5.1
Nonsense	3.1	3.0	3.0	3.0	3.0	2.8	2.9	2.8	2.7	3.1
Average	**5.1**	**5.0**	**4.9**	**4.9**	**4.8**	**4.7**	**4.8**	**4.7**	**4.7**	**4.8**

Alcohol tolerance, such as is discussed by Pringsheim[c] and Schweisheimer[d] in their biochemical researches, probably develops too slowly to produce much, if any, change in the results of our studies. On the other hand, the more pronounced changes of efficiency found in the second series of experiments with these subjects can hardly be ascribed to an accumulative effect, as in each case the repetition tests were well removed from the initial series.

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[a] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, pp. 126 to 131.

[b] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915.

[c] Pringsheim, Biochem. Zeitschr., 1908, 12, p. 143.

[d] Schweisheimer, Deutsch. Arch. f. klin. Med., 1913, 109, p. 271.

It is our belief that factors of habituation and subjective attitude are the probable cause for this observed change. As the experimental routine became better established and more a matter of regular everyday work, the mental attitude and behavior were more natural and the subject was not so constantly or keenly aware of being tested. To quote from the former report: "While Subject VI served willingly and seemed to cooperate in the measurements, one constantly had the impression that he was not trying hard in the tests in which voluntary functions were involved."[a] Under these circumstances, the alcohol as a psycho-dynamic influence was not so frequently struggled against by autogenic reinforcement and the more typical intensity of alcohol effect was revealed.[b]

The results from these repetition experiments indicate the important probability that when alcohol is taken in connection with the everyday routine occupation, the resulting decrease in efficiency may be larger than the effects usually observed in laboratory experiments with the same amounts and dilution conditions of dosage. In the typical unprejudiced laboratory study, the experimenter with his program of tests practically makes this challenge to the subject: "Can you do as well after the ingestion of alcohol as without it?" The whole experiment revolves around the subject; the swallowing of the alcohol is a mere incident, after which he is supposed to concentrate attention on his tasks; his performance is the center of interest and he is stimulated to do his best. Outside the laboratory the alcoholic beverage is taken voluntarily and there is reason to suppose that the individual is willing and desirous of at least a mild alcohol effect which will not be subjectively resisted unless unusual circumstances present themselves afterwards.

In conclusion, one individual has been used as a subject in two series of experiments. All the conditions were as nearly the same as possible, except that in the second series the experiments continued 2 hours longer and were 1 hour nearer to the time of taking the last food. The alcohol effect in the second series was in the same direction and larger than that shown in the first, i. e., ethyl alcohol as an influencing agent has increasing effect on efficiency under conditions of well-established routine. Therefore the probability exists that the alcohol effect is stronger in a practical way when the beverage is taken outside the laboratory and without the stimulating influence of laboratory tests. Experiments continuing for 4½ hours after the ingestion of 24 to 36 grams of alcohol exhibit an increase in typewriting errors throughout this time. The maximal decrease in efficiency is found about 1½ hours after the ingestion of alcohol.

INFLUENCE OF FOOD ON THE EFFECT OF ALCOHOL.

Repetition series of experiments were likewise performed on two other men of the group of typists, *Fam* and *Mih*. Both were very good operators and held excellent positions in the city. In the evening following their office work, which was not heavy during this period, they came to the Laboratory for the alcohol experiments. The first series for each man differed from the alcohol typewriting experiments previously discussed in that the subject ate a large meal at the Laboratory immediately before beginning the evening's work. These two subjects had by arrangement taken an unusually light luncheon and were ready for a full meal. The food was prepared at the Laboratory and was essentially uniform as to variety and quantity. It consisted of beefsteak, boiled potato, bread and butter, and whole milk. For our comparison purposes it is not necessary to give the weighed quantity actually consumed of each of these food materials, although these data were kept in the protocols. It is sufficient to note that the energy content of the meal for *Fam* was approximately 1,900 calories and for *Mih* 1,600 calories. The men were not required to eat a certain quantity, and each subject showed some variation in the amount consumed in successive days. Some other individual always ate with the subject, so as to make the food consumption seem less a matter of experimental routine.

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[a] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 14.

[b] Seemingly the "accumulative alcohol effects" sometimes reported in the literature might at least be partly explained in this way.

Immediately after the meal, the initial arrangements for the experiment were made; the preliminary period was completed and the dose for the evening ingested about 45 minutes after the meal was finished. On two preliminary days a somewhat longer period elapsed between the finishing of the meal and the taking of the dose, but these preliminary days are not included in our comparison results, and are part of the necessary adaptation of the subject to the routine procedure. Each experiment was about 5 hours in length. *Fam* was able to complete 8 periods in this time, while *Mih,* who wrote somewhat faster, could complete 10 periods. The net body-weight of *Fam* was about 53 kg. and of *Mih* 75 kg. Dose A for each man was adjusted to approximate 0.5 c. c. of absolute ethyl alcohol per kilogram of body-weight. This equaled 26 c. c. for *Fam* and 35 c. c. for *Mih,* or 21 and 28 grams of ethyl alcohol, respectively. In both cases it was given in a concentration of 14 per cent by weight. Dose B was approximately 50 per cent larger than dose A, so that the amounts given were 40 c. c. and 53 c. c., or (see table 1) 32 and 42 grams, respectively, for *Fam* and *Mih.* Dose B was given in a concentration of about 21 per cent by weight. The control doses were of the same volume and content, except for the alcohol, and as usual in these experiments, an effort was made to mask the control dose by wiping the rim of the glass with strong alcohol just previous to the ingestion of the beverage. Each subject, in his second series, had the same alcoholic dosage as in the first series, but the taking of the alcohol was separated from the previous food by about 3 hours in the case of *Fam* and more than 5 hours in the case of *Mih.* Otherwise, the experimental procedure for the first and second series was as nearly the same in reference to time of day, duration of experiment, and all other routine as can be procured in a repetition series.

Effect of Alcohol With and Without Food in Comparison Experiments With Fam.

Our comparisons in these two repetition series, on which the influence of food in the stomach is the factor under consideration, need not go beyond a discussion of the typewriting results, for these are perfectly typical. The comparison will be made separately for each man. The average results for the percentage of errors in typewriting are shown for *Fam* in table 28. This table is arranged in the same general form as table 24 for the comparison series with *Roj*. At the left of the table, the kind of typewriting task (practice, prose, or nonsense) is indicated with the dosage. The experimental series is also given, I being with food and II without food. The number of periods is the same for each experimental series, the seven 30-minute periods following the dosage representing approximately 4 hours. A plus sign denotes an increase in the number of errors following alcohol, while a minus sign specifies a decrease in the number of errors. In the whole table there are more than twice as many plus signs as there are minus. For series I, including all periods and the three kinds of typewriting results, there are 17 minus values, 23 plus values, and two zeros. This includes the results for both doses A and B. For series II, there are 7 minus values and 35 plus values. Minus values are noteworthy for the first series (with food) with dose A. The combined averages for all three typewriting tasks for the periods in order are −7.9, −23.7, −37.2, −69.6, −26.1, −9.7, and +24.1. These results, while not in apparent agreement with the rest of the picture, can not be discounted, for the two methods of computing, i. e., from preliminary differences and by direct comparison, show very closely agreeing values, so the average appears to be just. The results for dose A, series II, when the alcohol was taken on a comparatively empty stomach, indicate increases in errors from periods 2 to 6, ranging from about 10 to 57 per cent. Series I for dose B shows a fairly large increase in typewriting errors, but in series II with the same dose there was a larger increase.

TABLE 28.—*Percentage change in errors of typewriting following ingestion of alcohol by Fam with and without food.*

[*Fam* I, alcohol taken soon after food; *Fam* II, alcohol taken on empty stomach.]

Typewriting material, series, and dose.	Percentage change in errors for periods after dose.						
	2	3	4	5	6	7	8
Practice:							
Fam I A.....	−48.7	− 48.1	− 66.7	− 78.4	− 67.5	− 49.8	+49.8
Fam II A.....	+18.8	− 63.8	+ 56.3	+ 72.1	+121.6	+ 40.2	+67.5
Fam I B.....	+49.5	− 32.9	+ 96.2	+ 36.4	+ 24.9	+ 31.6	+ 9.1
Fam II B.....	−20.9	+128.4	+123.0	+ 8.4	+ 34.1	+ 20.2	−38.3
Prose:							
Fam I A.....	+12.8	− 22.9	− 21.8	− 65.9	− 34.7	+ 6.6	+ 6.6
Fam II A.....	+18.7	+ 35.0	+100.2	+ 64.4	+ 28.4	+ 12.9	+27.5
Fam I B.....	+ 7.4	+ 13.4	− 13.1	± 0.0	+ 12.7	− 13.1	−13.1
Fam II B.....	+ 2.5	+ 28.9	+ 2.5	− 2.5	+ 27.5	+ 12.3	+12.1
Nonsense:							
Fam I A.....	+12.3	± 0.0	− 23.0	− 64.5	+ 23.8	+ 14.2	+16.0
Fam II A.....	− 5.4	+ 67.5	+ 6.4	+ 34.8	+ 21.2	− 66.0	−42.2
Fam I B.....	− 8.3	+ 19.5	+ 41.0	+ 0.4	+ 25.7	+118.0	+58.4
Fam II B.....	+ 6.3	+ 57.0	+128.2	+168.2	+ 14.3	+ 41.3	+75.6
Average:							
Fam I A.....	− 7.9	− 23.7	− 37.2	− 69.6	− 26.1	− 9.7	+24.1
Fam II A.....	+10.7	+ 12.9	+ 54.3	+ 57.1	+ 57.1	− 4.3	+17.6
Fam I B.....	+16.2	± 0.0	+ 41.4	+ 12.3	+ 21.1	+ 45.5	+18.1
Fam II B.....	− 4.0	+ 71.4	+ 84.6	+ 58.0	+ 25.3	+ 24.3	+16.5

The percentage changes in the speed of typewriting in the two series with *Fam* after the ingestion of alcohol are given in table 29. Alcohol did not produce much change in the speed of typewriting with this man. There is no striking difference between the two experimental series observable in this table; plus and minus signs are about equally frequent, but in the second series (without food) there are relatively fewer plus values, and therefore on the whole a slightly slower writing rate.

The changes with this subject after alcohol can be readily seen in the summary table 30, in which the values for the first and second 2-hour periods are grouped for averaging, and the final results given for changes in errors and speed of typewriting after both dose A and dose B for the three kinds of typewriting tests. Averaging all of the results, in the first 2 hours following the ingestion of dose A (periods 2 to 5), we find in series I, with food, that there is a reduction in errors of 34.6 per cent, with a diminution in speed of 9.4 per cent. In series II, after the same amount of alcohol but without food, there is an increase in error of 33.8 per cent, and a decrease in speed of 1.3 per cent. The same time interval with dose B, series I, with food, shows an increase in error of 17.5 per cent, and an accession of speed of 2.5 per cent, while series II, without food, gives an increase in error of 52.5 per cent and a diminution in speed of but 0.6 per cent. In the interval 2½ to 4 hours after the alcohol, that is, periods 6 to 8, inclusive, the results with dose A for series I, with food, shows a slight decrease in error of 4.3 per cent and an increase in speed of 5.7 per cent. In series II, without food, there was an increase in error of 23.4 per cent,

TABLE 29.—*Percentage change in number of strokes per second in typewriting following ingestion of alcohol by Fam with and without food.*

[*Fam* I, alcohol taken soon after food; *Fam* II, alcohol taken on empty stomach.]

Typewriting material, series, and dose.	Percentage change in number of strokes for periods after dose.						
	2	3	4	5	6	7	8
Practice:							
Fam I A	−9.6	−15.1	−13.3	− 8.1	+13.8	+ 6.3	+ 2.7
Fam II A	+0.8	− 0.8	+ 0.8	− 5.6	+ 0.9	− 0.8	− 8.8
Fam I B	−2.6	+ 6.2	+ 0.9	+ 6.2	+11.9	+ 2.7	+ 2.6
Fam II B	+3.3	+ 1.7	+ 1.7	+ 3.2	+ 9.9	± 0.0	+ 3.2
Prose:							
Fam I A	−4.9	−13.1	−10.9	− 5.3	+ 7.2	+15.5	+13.2
Fam II A	−1.8	+ 0.1	+ 5.6	− 1.8	+ 5.7	± 0.0	− 1.8
Fam I B	+6.9	+ 3.0	+ 1.0	+ 7.2	+ 9.1	+ 9.2	+ 1.0
Fam II B	−3.7	+ 1.9	+ 3.8	− 3.6	+ 3.8	+ 1.9	+ 3.6
Nonsense:							
Fam I A	−7.1	− 6.2	−11.8	− 7.3	− 5.2	− 4.3	+ 2.4
Fam II A	±0.0	± 0.0	− 3.1	−10.1	+ 1.0	− 3.5	− 1.8
Fam I B	+1.3	+ 1.8	− 0.7	− 1.2	− 1.7	− 2.2	+ 1.9
Fam II B	−1.8	− 4.8	+ 2.2	−10.1	− 1.1	− 4.4	− 2.8
Average:							
Fam I A	−7.2	+11.5	−12.0	− 6.9	+ 5.3	+ 5.8	+ 6.1
Fam II A	−0.3	− 0.2	+ 1.1	− 5.8	+ 2.5	− 1.4	− 4.1
Fam I B	+1.9	+ 3.7	+ 0.4	+ 4.1	+ 6.4	+ 3.2	+ 1.8
Fam II B	−0.7	− 0.4	+ 2.6	− 3.5	+ 4.2	− 0.8	+ 1.3

with a slight decrease in speed of 1.0 per cent. With dose B there is an increase of error in both series, i. e., 28.3 per cent in the first and a somewhat smaller percentage of 22 per cent in series II. There is an actual increase in speed, also, in both series, but this was less in the experiments in which no food preceded the alcohol (series II).

TABLE 30.—*Comparison of effect of alcohol in first and second 2-hour periods in typewriting experiments with Fam with and without food.*

[*Fam* I, alcohol taken soon after food; *Fam* II, alcohol taken on empty stomach.]

Typewriting material and series.	Percentage change in periods 2 to 5.				Percentage change in periods 6 to 8.			
	Dose A.		Dose B.		Dose A.		Dose B.	
	Errors.	Speed.	Errors.	Speed.	Errors.	Speed.	Errors.	Speed.
Practice:								
Fam I......	−60.5	−11.5	+37.3	+2.7	−23.8	+ 7.6	+21.9	+5.7
Fam II......	+20.9	− 1.2	+59.7	+2.5	+76.4	− 2.9	+ 5.4	+4.4
Prose:								
Fam I......	−24.5	− 8.6	+ 2.0	+4.5	− 7.2	+12.0	− 4.5	+6.4
Fam II......	+54.6	+ 0.5	+ 7.9	−0.5	+22.9	+ 1.3	+17.3	+3.1
Nonsense:								
Fam I......	−18.8	− 8.1	+13.1	+0.3	+18.0	− 2.4	+67.4	−0.7
Fam II......	+25.9	− 3.3	+90.0	−3.7	−29.0	− 1.5	+43.4	−0.2
Average:								
Fam I......	−34.6	− 9.4	+17.5	+2.5	− 4.3	+ 5.7	+28.3	+3.8
Fam II......	+33.8	− 1.3	+52.5	−0.6	+23.4	− 1.0	+22.0	+2.4

EFFECT OF ALCOHOL WITH AND WITHOUT FOOD IN COMPARISON EXPERIMENTS WITH MIH.

The data for the comparison series with *Mih,* the other subject on whom experiments with and without food were made, need not be discussed in so much detail as the results for *Fam.* The difference between series I and II with *Mih* is in the same direction as that noted with *Fam,* but is more prominent. Table 31, which gives a summary of the effect of alcohol on the percentage of typewriting errors, contains many values which are larger than those found in table 28, and these are nearly always plus in direction, indicating an increase in the number of typewriting errors. The composite averages for the typewriting errors at the bottom of the table are all plus values in series II with both doses, and the increases are very prominent. The parallel figures for series I, when the subject had had food, are usually of smaller denomination and fluctuate in sign.

In table 32, in which data regarding the effect of alcohol on the speed of typewriting are grouped for the two series with *Mih,* minus values predominate, indicating a general decrease in speed. In the combined typewriting averages for series I with dose A, the general direction of the change is a decrease in speed, but the decrease in series II, when the subject was without food, is considerably more prominent. The same characteristics are found when the two series after dose B are compared as to the effect of alcohol on the speed of typewriting.

TABLE 31.—*Percentage change in errors of typewriting following ingestion of alcohol by Mih with and without food.*

[*Mih* I, alcohol taken soon after food; *Mih* II, alcohol taken on empty stomach.]

Typewriting material, series, and dose.	Percentage change in errors for periods after dose.						
	2	3	4	5	6	7	8
Practice:							
Mih I A	−15.4	+24.1	+11.2	+42.3	+114.4	+11.6	−73.3
Mih II A	+14.8	+213.4	+3.7	+14.0	+62.0	+9.0	−35.3
Mih I B	−20.0	+39.4	−2.9	+7.1	−15.9	−4.5	−44.0
Mih II B	−11.1	+180.5	+22.0	+50.0	−31.0	+7.9	−70.8
Prose:							
Mih I A	−33.3	+17.1	+6.1	−29.3	+17.1	+5.6	−1.6
Mih II A	+112.5	+200.0	+189.3	+85.0	+93.3	+39.6	+61.7
Mih I B	−1.4	+21.9	+6.6	−15.0	+15.7	+28.2	+28.2
Mih II B	+139.9	+181.4	+119.1	+62.5	+138.9	+41.6	+47.6
Nonsense:							
Mih I A	−60.9	−5.9	−27.6	−36.2	+16.5	+9.2	−28.2
Mih II A	+33.8	+109.5	−44.5	+1.3	−15.0	+19.6	+81.4
Mih I B	−16.6	−16.6	−34.8	−10.3	+60.6	+53.8	+39.5
Mih II B	+413.3	+153.3	+203.6	+13.4	+46.7	+34.3	+128.6
Average:							
Mih I A	−36.5	+11.8	−3.4	−7.7	+49.3	+8.8	−34.4
Mih II A	+53.7	+174.3	+49.5	+33.4	+46.8	+22.7	+35.9
Mih I B	−12.7	+14.9	−10.4	−6.1	+20.1	+25.8	+7.9
Mih II B	+180.7	+171.7	+114.9	+42.0	+51.5	+27.9	+35.1

TABLE 32.—*Percentage change in number of strokes per second in typewriting following ingestion of alcohol by Mih with and without food.*

[*Mih* I, alcohol taken soon after food; *Mih* II, alcohol taken on empty stomach.]

Typewriting material, series, and dose.	Percentage change in number of strokes for periods after dose.						
	2	3	4	5	6	7	8
Practice:							
Mih I A	−0.8	−2.4	+0.8	−5.6	−4.1	−0.8	−2.5
Mih II A	−2.3	−11.5	−8.5	−7.1	−3.9	+0.8	−0.8
Mih I B	−1.6	−1.6	−4.8	−4.8	−3.3	−3.3	−1.7
Mih II B	−3.9	−11.5	−8.5	−7.0	−3.9	−3.9	+0.8
Prose:							
Mih I A	±0.0	±0.0	−3.6	−1.8	−5.4	−1.8	−3.6
Mih II A	−4.5	−16.5	−15.1	−9.7	−2.7	−4.5	+2.8
Mih I B	±0.0	−1.8	−7.2	−7.0	−10.7	−7.1	−5.5
Mih II B	−2.7	−18.3	−13.3	−6.2	−6.3	−6.2	+1.0
Nonsense:							
Mih I A	+2.5	−3.8	+3.2	+0.3	±0.0	−3.5	−9.6
Mih II A	−0.2	−5.2	−3.7	+2.2	+8.8	+8.0	+1.2
Mih I B	+4.9	+2.1	−2.7	+1.5	+4.4	−4.1	+3.4
Mih II B	−23.0	−15.4	−12.0	−4.5	−1.0	−1.9	−1.0
Average:							
Mih I A	+0.6	−2.1	+0.1	−2.4	−3.2	−2.0	−5.2
Mih II A	−2.3	−11.1	−9.1	−4.9	+0.7	+1.4	+1.1
Mih I B	+1.1	−0.4	−4.9	−3.4	−3.2	−4.8	−1.3
Mih II B	−9.9	−15.1	−11.3	−5.9	−3.7	−4.0	+0.3

A summary of the values obtained with *Mih* is given in table 33, with the results averaged for the first and second 2 hours (periods 2 to 5, and 6 to 8, inclusive). The general comparative results for this subject in the two series are fairly clear cut. In the first 2 hours of series I, with dose A, preceded by food, there is a decrease of 9 per cent in error and a slight decrease in speed of 1 per cent. With the same dose in series II, when the subject was without food, there is an increase of error in the first 2 hours of 77.7 per cent, and a decrease in speed of 6.9 per cent. With dose B, in series I, with food, there is a slight decrease in error of 3.5 per cent, and as before a slight decrease in speed of 1.9 per cent. With the same dose in series II, without food, there is a still larger increase in error of 127.3 per cent, and a considerable decrease in speed of 10.5 per cent. In the second 2-hour period (periods 6 to 8) covering an interval 2½ to 4 hours following the ingestion of alcohol, the averages for series I with dose A and with food preceding reveal some increase in error (7.9 per cent), with a decrease in speed of 3.5 per cent, while series II, with the same dose, shows a larger increase in errors of 35.2 per cent, but no decrease in speed; there was, in fact, a slight increase in the number of strokes per second of 1.1 per cent. With dose B, which was 42 grams of alcohol with this individual, with a concentration of 21 per cent, in series I there was an increase in error of 17.9 per cent, with a decrease in speed of 3.1 per cent. In series II there was a larger increase in error of 38.2 per cent, but not quite so much of a decrease in speed, this being but 2.5 per cent.

TABLE 33.—*Comparison of effect of alcohol in first and second 2-hour periods in typewriting experiments with Mih with and without food.*

[*Mih* I, alcohol taken soon after food; *Mih* II, alcohol taken on empty stomach.]

Typewriting material and series.	Percentage change in periods 2 to 5.				Percentage change in periods 6 to 8.			
	Dose A.		Dose B.		Dose A.		Dose B.	
	Errors.	Speed.	Errors.	Speed.	Errors.	Speed.	Errors.	Speed.
Practice:								
Mih I....	+15.6	−2.0	+5.9	−3.2	+17.6	−2.5	−21.5	−2.8
Mih II....	+61.5	−7.4	+60.4	−7.7	+11.9	−1.3	−31.3	−2.4
Prose:								
Mih I....	−9.9	−1.3	+3.1	−4.0	+7.0	−3.6	+24.0	−7.8
Mih II....	+146.7	−11.5	+125.7	−10.1	+64.9	−1.5	+76.0	−3.9
Nonsense:								
Mih I....	−32.7	+0.4	−19.6	+1.5	−0.8	−4.4	+51.3	+1.3
Mih II....	+25.0	−1.7	+195.9	−13.7	+28.7	+6.0	+69.9	−1.3
Average:								
Mih I....	−9.0	−1.0	−3.5	−1.9	+7.9	−3.5	+17.9	−3.1
Mih II....	+77.7	−6.9	+127.3	−10.5	+35.2	+1.1	+38.2	−2.5

The conclusions to be drawn from these two sets of repeated experiments with *Fam* and *Mih* are obvious. The one factor which was consciously varied was the presence and the amount of food in the stomach. The alcohol dosage, the experimental tests, the time of day, etc., were otherwise identical. The food was used in the first series and two preliminary days were employed. The second series without food occurred approximately two months later and, in each case, one preliminary day was used. Both subjects revealed the fact that when the alcohol was taken shortly after the ingestion of a full meal the effect, as exhibited in the accuracy and speed of neuro-muscular processes during a 4-hour interval following ingestion, was very much reduced and considerably delayed in its appearance as compared with the effect found when the alcohol was taken 3 to 5 hours after food. The natural inference to be drawn from this comparison is that the presence of food in the stomach sufficiently dilutes the alcohol and retards its absorption, so that the toxic effect is considerably reduced and the maximal effect is delayed roughly 2 hours. When we judge entirely from these data and use the accuracy of typewriting as a measure of the alcohol influence, it is conservative to estimate that the effect is several times larger when the alcohol dose is taken on an empty stomach than when it is taken in close proximity to a full meal.

Although food as a factor modifying the influence of alcohol on the organism has not received direct experimental attention at all commensurate with the practical importance of this problem, there are some observations scattered in alcohol literature which may be cited in connection with our results obtained in 1915. Weissenfeld,[a] in studying respiration and circulation on himself, found that the changes produced after alcohol were largest when the 13.7 per cent of alcohol in wine was taken on an empty stomach. Völtz, Baudrexel, and Dietrich,[b] in experimenting with men to whom they gave 0.8 c. c. absolute alcohol per kilogram of body-weight, report seven times as much alcohol in the urine when the dosage was without food. The influence particularly of lipoidal substance on alcohol absorption is reviewed by Hanzlik and Collins,[c] who give several references. In their own experiments with ligated loops of cat intestine, small amounts of olive oil mixed with the alcohol reduced the absorption 27 per cent. Dodge and Benedict[d] had one subject (X) who took a full meal just before the alcohol experiments. He demonstrated less than the average alcohol effect in the psychological tests used by these authors. In reporting some experiments on alcohol and marksmanship, Kraepelin[e] observed that in the afternoon tests following the midday meal the alcohol effect was much less than when the alcohol was taken on an empty stomach. Recently, British workers, at the request of the Central Control Board of the Liquor Traffic, have also attacked this problem on the influence of food on the toxic action of alcohol and have accumulated much evidence. Vernon[f] remarks (pp. 58, 59) on the curious lack of data in regard to food in the earlier alcohol literature. He gives no references, but briefly reports several experiments on alcohol and typewriting with results which closely resemble ours on *Fam* and *Mih*. When the alcohol was taken with food, the effect was much delayed and only about one-half as large.[a] The effect of food in the alimentary canal on the absorption of alcohol, measured by the amount of alcohol appearing in the blood of dogs at intervals after ingestion, was extensively studied by Mellanby.[b] He found that foods, especially whole milk, delayed the appearance of the maximal alcohol concentration in the blood and invariably depressed it.[c] Finally, McDougall and Smith,[d] using a highly complicated coordination test, have published two series of results. The ingestion of 30 c. c. of absolute alcohol, diluted to 60 c. c. with water, immediately after a small meal, gave an increase in errors of only 6 per cent, but when the alcohol was taken from 2 to 11 hours after the last food (usually 4¼ hours), the alcohol effect was a change of 118 per cent.

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[a] Weissenfeld, Arch. f. d. ges. Physiol., 1898, **71**, p. 60; Vogt, Norsk Magazin f. Laegevidenskaben, 1910, 8, p. 605, confirms this and states that 20 to 25 c. c. of alcohol without food gave a stronger effect on memory than did 50 c. c. with food.

[b] Völtz, Baudrexel, and Dietrich, Arch. f. d. ges. Physiol., 1912, **145**, p. 210.

[c] Hanzlik and Collins, Journ. Pharm. and Exp. Therapeutics, 1913, **5**, p. 185.

[d] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 263, table 50; see also Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, pp. 137 and 139.

[e] Kraepelin, Internat. Monatsschr. z. Erforsch. d. Alkoholismus, 1916, 26, Hft. 10–11.

[f] Vernon, Med. Research Com., Sp. Rpt., Ser. No. 34, London, 1919.

In these quoted results, as in the data for *Fam* and *Mih*, obviously both repetition and food are involved. We may go a little way in disentangling the two factors, using typewriting errors as our index of alcohol effect:

Average errors for periods 2 to 5 and for doses A and B.

	First series	Second series
Lig and *Suf*	No food, +37 per cent	(No repetition experiments)
Roj	No food, +27 per cent	No food, +75 per cent
Fam and *Mih*	With food, − 7 per cent	No food, +73 per cent

Fam and *Mih* without food in the second series compare well with *Roj* under the same conditions. But the results of the first series with *Fam* and *Mih* with a meal just before the experiment, when compared with those for *Roj*, *Lig*, and *Suf*, who did not have food, show a marked difference. The typing efficiency of the latter subjects suffered 27 to 37 per cent; that of *Fam* and *Mih* was, in fact, a little better than normal, the result being −7 per cent. (During periods 6 to 8, their average was +12 per cent.) These results which do not involve repetition as a factor strongly indicate that food taken with alcohol reduces the intensity of toxic influence, delays the maximal effect, and through retardation of absorption delays the disappearance of alcohol from the organism.

CONCLUSIONS AS TO THE EFFECT OF REPETITION AND FOOD.

The two factors which have been the objects of direct experimentation and discussion in this chapter seem to modify the alcohol effect in opposed directions. With mere repetition of experimental routine the toxic influence is more prominent, suggesting that the alcohol effect usually found in the laboratory is probably not so large as exists outside the laboratory. The taking of food just before or with the alcohol causes a marked decrease in the intensity of effect produced, a result which is substantiated by the experiences of everyday life.

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[a] In Dr. Vernon's paper, page 49, figure 12, measurements were made at intervals of two or more hours and it can hardly be assumed that the exact points of maximal effect were found. The smoothing of the curves has been carried to an extreme.

[b] Mellanby, Med. Research Com., Sp. Rpt., Ser. No. 31, London, 1919, p. 22.

[c] Salzmann (1912), quoted by Thunberg, Alkoholens Fysiologiska Verkningar, Stockholm, 1920, p. 30, found that 1.6 to 2.0 grams of alcohol per kg. of body-weight given with cream to cats produced almost no effects, while 1.2 grams per kg. given in water definitely influenced the behavior.

[d] McDougall and Smith, Med. Research Council, Sp. Rpt., Ser. No. 56, London, 1920, p. 32.

CHAPTER IV.

EFFECT OF DILUTE ALCOHOL GIVEN BY RECTAL INJECTION DURING SLEEP.

Dr. T. M. Carpenter, of the Nutrition Laboratory, has made a large number of experiments in which he studied the metabolism following the introduction of various substances by rectal injection. In some instances dilute solutions of ethyl alcohol were employed. At no little inconvenience to his own experimental procedures, Dr. Carpenter kindly gave the author the opportunity to make psychological and other measurements on one of the men who served in all-night experiments when alcohol solutions were used.

PROGRAM OF RECTAL FEEDING EXPERIMENTS.

The subject came to the Laboratory about 6 p. m., having taken his last previous food, usually a heavy meal, 5 hours before. A series of neuromuscular measurements, continuing about 1½ hours, was first made on him in the psychological laboratory. The subject then went to Dr. Carpenter's room, took a cleansing enema, and began the all-night experiment. For this he lay down in the clinical respiration apparatus,[a] which is of the closed-circuit type, with a chamber completely inclosing the subject while he is in a prone position. Pneumographs were arranged to register any body activity during the night, a stethoscope was secured in position over the apex beat of the heart for counting the heart-rate, electrodes (to be described later) were attached to both wrists and the left ankle for the taking of standard electrocardiograms during the night, and the catheter through which the alcohol or control solution was to be passed was inserted in the subject's rectum. When the man had lain quietly for a considerable time after the making of these adjustments, the cover of the chamber was lowered into position and the metabolism experiment began. These metabolism measurements were continuous throughout the night. By the use of a clock and an electric signal, a sound was periodically produced near the subject's head. If awake, he responded to this by pressing an electric button comfortably attached to the hand. Usually by 9 p. m. all was in readiness for the metabolism experiment and the chamber closed. The subject invariably went to sleep soon after that time. The rectal injection began about 2½ hours later. The actual time in each case for the six all-night experiments is indicated in table 34, which gives the chronological arrangement and protocols for the rectal feeding experiments that were associated with the psychological measurements. Dr. Carpenter gave the injection of the alcohol solution or salt solution very slowly by the drop method, using a gravity fall of about 1 meter. The injection required approximately 2 hours and did not waken the subject. Following the completed injection, there was a period of 4 hours during which the metabolism was studied while the subject was sleeping. About 5^h30^m to 6 a. m., the cover to the respiration apparatus was lifted, the subject was awakened, and a half-face mask put in place. Then the metabolism measurements

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[a] Benedict and Tompkins, Boston Med. and Surg. Journ., 1916, **174**, pp. 857, 898, 939.

TABLE 34.—*Chronological arrangement of the rectal feeding experiments.*

Date.	Type of experiment.	Previous food.	Evening tests.	Rectal injection during night.	Sets of electro-cardiograms taken.	Morning tests.
1917 Feb. 9–10.	Control....	Lunch at 12^h30^m p. m.; had heavy breakfast.	5^h15^m to 8^h15^m p. m.[1]	500 c. c. of 0.6 p. ct. salt solution given 12^h15^m a. m. to about 2 a. m.	8 sets taken from 10^h30^m p. m. to 6^h15^m a. m.	6^h45^m to 8 a. m.
Feb. 15–16.	Alcohol....	Heavy meal at 12^h30^m p. m.	6 to 7^h30^m p. m.[2]	500 c. c. of 7.5 p. ct. ethyl alcohol given 11^h32^m p. m. to 1^h30^m a. m.	11 sets taken from 10^h15^m p. m. to 7^h05^m a. m.	7^h45^m to 9 a. m.
Mar. 2–3.	Alcohol....	Heavy meal at 1^h40^m p. m.	5^h45^m to 7^h35^m p. m.	500 c. c. of 7.5 p. ct. ethyl alcohol given 9^h40^m p. m. to 12^h12^m a. m.	None taken[3]..........	7^h30^m to 8^h45^m a. m.
Mar. 16–17.	Control....	Full meal at 12^h50^m p. m.	5^h30^m to 6^h55^m p. m.	No injection[4]......................	10 sets taken from 9 p. m. to 6^h45^m a. m.	7^h15^m to 8^h30^m a. m.
Mar. 23–24.	Alcohol....	Full meal at 12^h45^m p. m.	6^h05^m to 7^h20^m p. m.	500 c. c. of 7.5 p. ct. ethyl alcohol given 11^h36^m p. m. to 1^h37^m a. m.	14 sets taken from 8^h50^m p. m. to 6^h30^m a. m.	7^h20^m to 8^h25^m a. m.
Apr. 2–3.	Control[5]...	Light meal at 12^h30^m p. m.	5^h50^m to 7^h05^m p. m.	500 c. c. of 0.6 p. ct. salt solution given 12^h05^m to 1^h21^m a. m.	10 sets taken from 9^h15^m p. m. to 6^h35^m a. m.	7^h22^m to 8^h20^m a. m.

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[1] The first hour was devoted to an intensive practice, demonstration, and coaching period in the seven measurements which were to be used. *Ius* had served as a subject in somewhat similar tests at another laboratory and readily understood the directions.

[2] Up until 1 a. m. the previous night and complained of being sleepy.

[3] The galvanometer string became non-conducting during the evening psychological tests and the instrument could not be repaired in time to take the standard electrocardiograms.

[4] Quite early in the experiment the tube leading to the catheter was accidentally broken. As this passed under the chamber hood, connection could not be remade without opening the chamber and awakening the subject. Dr. Carpenter had intended giving salt solution so the injection was omitted.

[5] Dr. Carpenter's protocols show that *Ius* on this night had a slight febrile temperature with an increase in pulse-rate, but he did not complain of any discomfort.

were continued by the Carpenter gasometer method, but with the subject awake. As indicated in table 34, five all-night series of standard electrocardiograms were taken. These covered the conditions with the subject asleep before injection, during injection, in the 4-hour period following injection, and also in the morning period with the subject awake.

When the period of gasometer measurements was completed, the subject left the apparatus, urinated (the sample was retained and analyzed for alcohol content), and came down stairs for the morning psychological tests, which were taken under post-absorptive conditions. Before these measurements began, he washed his face and hands, reported his general condition, and adjusted himself mentally and physically for the work to be done.

SUBJECT AND DOSAGE.

Our subject in these experiments, *Ius,* was a student at the Harvard Medical School. He was about 25 years of age and of spare build, with a height of 169.2 cm. and a nude body-weight of 57.6 kg. *Ius* was in good health and used to taking small amounts of alcohol in the form of beer. He was a very intelligent and cooperative subject. He had served previously in some psychological observations, so that after the first hour of intensive instruction and practice, he understood very well what was expected of him and was able to assist considerably in the adjustment of the apparatus. *Ius* took an unusual interest in the technique of the measurements and apparently tried uniformly to do his part well.

As seen in table 34, the first experiment was a control test, the second and third alcohol, the fourth control, the fifth alcohol, and the sixth control. On each occasion, with the exception of the fourth experiment, when an accident happened to the rectal feeding apparatus, 500 c. c. of liquid were gradually injected. The water was given at room temperature and in the control experiments contained 0.6 per cent salt. In the three alcohol experiments the liquid was a solution of ethyl alcohol and water containing 7.5 per cent by weight of alcohol. In each alcohol experiment, therefore, the man received 37.5 grams, or 47 c. c., of absolute alcohol, which, in this case, is equivalent to 0.8 c. c. per kilogram of body-weight.

The writer did not know until the six experiments were completed which were control and which were alcohol. Dr. Carpenter had entire charge of the protocols in reference to the solutions given, and these were not seen until the data had been completed. This was probably a needless precaution, but the intention was to be especially unprejudiced in reference to the results, as it was anticipated that the effect on the morning's performance would be very slight, if, indeed, observable. The subject, on his own part, was unable to tell with any assurance whether he had received alcohol, dextrose, levulose, or salt solution during the night. All of these substances were being used. To the subject's knowledge it was not a strictly alcohol experiment, but one with rectal feeding.

PROGRAM OF MEASUREMENTS BEFORE AND AFTER RECTAL FEEDING OF ALCOHOL.

In the experimental session in the psychological laboratory which preceded and followed the metabolism experiments, seven measurements were used. These included pulse tracings during rest, short exertion, and recuperation; one reflex (the protective lid wink from sound stimulus); two sensory thresholds (visual acuity and sensitivity to electric shock); two motor coordinations (speed of finger movement and speed of horizontal eye movement); and one choice reaction test (eye reactions to peripheral stimuli). The techniques for the various measurements have been described in Chapter I.

The tests were always given in the following order and required approximately the time indicated:

	Minutes.
1. Electrical threshold: Direct current stimulation of the finger-tips with a large external resistance in series	8
2. Tetanus heart-rate: Electrocardiograms from body-leads during rest, quick intense exertion, and recuperation	5
3. Finger movements: Maximum number possible in 8 seconds	2
4. Visual acuity: Repeatedly tested in several axes with the Ives-Cobb acuity object.	8
5. Eye movements: The velocity of horizontal movements covering 40° on the arc of vision photographically recorded	6
6. Eye reactions: Quickness of turning the eye in the direction of a visual stimulus	5
7. Protective lid reflex: Latency and amplitude of wink produced by a sound stimulus[a]	6

On the first evening when the subject came to the Laboratory, all the measurements were carefully explained to him, preliminary trials were made, and he was instructed in performing these tests. Following this preliminary training there was a half-hour rest, and then the routine was carried through twice, that is, two complete series of measurements were made. On the following morning and on each succeeding evening and morning, two periods were completed. Each required about 40 minutes; therefore the time of testing, both prior to the metabolism experiment and after it in the morning, was very closely 1½ hours. The protocols do not reveal any special circumstances worthy of mention in connection with any evening or morning results.

COMPARISON OF RESULTS BEFORE AND AFTER ALCOHOL.

The results in this series of experiments need no very extended presentation. It was not planned to examine the subject's condition at several intervals following the alcohol, but only, if possible, to discover if there were any objectively demonstrable effects to be found in the morning at a time 6 to 7 hours after the completion of the rectal injection of the alcohol. The three control days are grouped, and all of the data collected for one measurement in the evening sessions are averaged. In like manner, all of the data for any single measurement collected in the morning sessions following the salt solution or control injection are averaged. The data before and after the alcohol injection are treated similarly. Thus, for final comparison on each test, we have four average values, one each for evening and for morning when no alcohol was given, and one each for evening and for morning when alcohol was injected during the night. For stating the alcohol effect in per cent, the procedure is simple and as follows: With both the control data and the alcohol data, the average of the evening values is subtracted from the average of the morning values. The difference thus obtained from the control experiments is then subtracted from the difference found for the alcohol experiments. The result represents the effect of the alcohol. The percentage effect is computed by using the average of the values for the control and alcohol evening experiments as the base. Due regard should be given to the algebraic sign and to its meaning for the measurement under discussion.

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[a] In the first practice period with the lid reflex, the stimulus noise was given about 25 times in succession in order that the subject might become used to it and overcome any tendency to jump or start at the sound.

A summary of the data and the effect of alcohol on the various tests is given in table 35. As a concrete illustration of the method of calculating the alcohol effect, the first measurement given in the table may be considered. This is the duration of the heart-cycle with the subject sitting quietly in the steamer chair resting prior to exertion. The average cycle length for the evening sessions of control experiments is 0.73 second and that for the morning sessions 0.72 second. The difference between these two control averages is −0.01 second. Similarly, the average for the evening sessions before the alcohol injection is 0.76 second and for the morning sessions, 0.66 second, with a difference between them of −0.10 second. Thus, in both the control and alcohol experiments, the pulse-cycle was shorter, representing a faster heart-rate in the morning than in the evening. The control difference subtracted from the alcohol difference gives a relative alcohol effect of −0.09 second. The percentage change after alcohol is then computed by using the average of the two evening values (0.75 second) as a base, giving a percentage effect of −12.0.

TABLE 35.—*Summary for the effect on various measurements of dilute alcohol given by rectal injection during sleep.*

Measurement and unit employed.	Control data.		Alcohol data.		Alcohol effect (p. ct.).
	Evening.	Morning.	Evening.	Morning.	
Heart-rate, cycle duration in seconds:					
During rest, sitting	0.73	0.72	0.76	0.66	−12.0
During exertion	0.61	0.61	0.61	0.56	− 8.2
During recuperation	0.58	0.58	0.65	0.56	−14.5
Lid reflex:					
Latency in σ	44.4	44.0	44.4	44.9	+ 2.2
Amplitude in mm.	2.5	3.8	3.4	4.7	± 0.0
Electrical threshold in volts	98.9	100.9	88.0	91.8	+ 1.9
Visual acuity in degree seconds	102.5	102.5	97.2	101.8	+ 4.6
Finger movements:					
No. in 2 seconds	17.1	17.6	17.7	17.9	− 1.7
No. in 4 seconds	33.3	34.5	34.6	35.1	− 2.1
No. in 6 seconds	49.1	50.8	51.0	51.5	− 2.4
Eye movements in σ:					
Adductive	115	113	112	117	+ 6.1
Abductive	106	100	100	97	+ 2.9
Eye reactions in σ	213	208	205	205	+ 2.4
General average effect					5.6

The duration of the heart-cycle when the subject was exerting himself is, on the average, the same for the evening and morning of control days, likewise for the evening of alcohol days (0.61 second) but is 0.56 second following alcohol. The effect of alcohol is, therefore, to shorten the cycle by 8.2 per cent. Following exertion, designated as "during recuperation," there is no difference between the values for evening and morning in the control data, but a distinct difference is found on the alcohol days. This difference is also in the direction of a faster rate, the change amounting to 14.5 per cent, as shown by a shortened duration of the heart-cycle. All three phases of these pulse data are therefore concordant as to the effect of alcohol and indicate pronounced increase in heart-rate. The percentage effect is smallest during exertion. This is in agreement with previous results when the same measurement was used in alcohol experiments with another subject.[a]

The averages for the latency of the lid reflex do not vary greatly among themselves. With the control data the latency is slightly greater in the evening than in the morning, but the conditions are reversed with the alcohol data. The effect is definite and amounts to an increase or slowing in latent time of 2.2 per cent. The lid-reflex amplitudes show considerable variation which result in this case in a zero effect. This is unusual, as previous studies at the Nutrition Laboratory have commonly revealed a stronger effect on the amplitude of reflexes than on the latency.

The two sensory thresholds (electrical threshold and visual acuity) are given consecutively in the table, but were well separated from each other in the experimental routine. These threshold measurements required more concentration of attention from the subject than the other tests employed. By placing one at the beginning of the series and the other midway in the program, the subject obtained a rest between the two. In the sensitivity of the finger-tips to single electric shocks (results measured in terms of voltage required to stimulate), the threshold is higher in the morning than in the evening for both control and alcohol days, but the alcohol averages are at a lower level than those for control and show a greater discrepancy between evening and morning, and the alcohol effect is in the direction of a higher threshold (less sensitivity) by 1.9 per cent.

The visual-acuity values resemble those for electrical threshold in that the averages for both evening and morning in the alcohol data are lower than in the control data. On the control days the evening and morning values are alike (102.5 degree-seconds). On the alcohol days the average evening threshold was 97.2 degree-seconds and the morning threshold, 101.8 degree-seconds. The effect of the rectal injection of alcohol is a higher threshold of 4.6 per cent, indicating a decrease in visual acuity at this time. The alcohol effect on sensory thresholds is perhaps not usually in this direction (see p. 167) and the change is also fairly large. The result has, of course, been computed by averaging all of the control data and contrasting this with the averages for all of the alcohol data. If we group the experiments chronologically by comparing the first control day with the first alcohol day, and compute the effect from these two days, and then do likewise for the second and third pairs of control and alcohol days, we have three 2-experiment series for comparison. These, in order as named, give alcohol effects on the visual acuity as +5.1, +5.0, and +4.0 per cent, with an average computed in this way of +4.7 per cent. The decrease, therefore, in visual acuity for this subject under the conditions of these experiments can not be doubted.

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[a] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 110.

The results for the speed of the finger movements are given in table 35 in terms of number of oscillations performed in 2 seconds, 4 seconds, and 6 seconds, separately. The finger movements were more rapid in the morning than in the evening, but this rapidity was more pronounced in the control data than in the alcohol performance. The effect of the alcohol is thus minus, or a less number of finger movements, by 1.7, 2.1, and 2.4 per cent for 2 seconds, 4 seconds, and 6 seconds, respectively. The alcohol effect for 4 seconds and 6 seconds is naturally modified by the result for 2 seconds, since the larger period of time always includes the shorter or earlier interval. If the number of oscillations made in 2 seconds is deducted from that made in 4 seconds, it will be found that in the second 2-second interval the alcohol effect was −2.4 per cent and similarly, if the number of finger movements performed in 4 seconds is deducted from the number performed in 6 seconds, the alcohol effect actually occurring in the third 2-second interval is −3.1 per cent. In this case, the alcohol effect is increasing with the prolongation of the test.

On the control days, both eye movements, like the finger movements, are quicker in the morning, but on the alcohol days, this is true only for the abductive movement. With both measurements, however, the difference between the evening and morning values is less on the alcohol days than on the control days; the eye movements are therefore found to be slower following the alcohol. Characteristically the effect is stronger on the adductive movement than on the abductive, the percentages being +6.1, and +2.9, respectively. The eye movement is a process of which the speed can be little, if at all, modified by effort of the subject; therefore the effect of alcohol upon this important coordination is all the more fundamental.

The averages for the eye reaction are at slightly different levels in the control and alcohol data. The reaction time appears quicker on the morning of control days than in the evening (208σ as compared with 213σ) but in the alcohol data the average speed of reaction is the same for both morning and evening (205σ). The effect of the alcohol in terms of averages is an increase in the length of the reaction time, amounting to 2.4 per cent, showing a relatively slower response to the stimulus.

The algebraic signs for the percentage effects in the last column of table 35 are not all alike. Obviously, they must each be considered in relation to the particular measurement to which they apply. In the typewriting data, as well as in other series of experiments reported here, it is common for the heart-rate to be quickened after alcohol. We therefore see that a shortening of the duration of the heart-cycle, a lengthening of the reflex time, less sensitivity in threshold measurements, less speed in finger movements and in eye movements, and a lengthening of the reaction time of the eye are all concordant results and show the ethyl alcohol as given in these experiments to have exercised a depressant action which decreased the general efficiency of the individual tested. The only exception is that of a zero effect in the amplitude of the lid reflex. As an approximate general statement of the effect of alcohol, we may take the average of all of these results without regard to sign, which is found to be a change of 5.6 per cent following the rectal injection of 37.5 grams of dilute alcohol.

In the study of the effect of ethyl alcohol on the physiological and particularly the psychological processes of the human organism, there is always the difficulty of a possible subjective bias or interference when the alcohol is given by mouth with the subject awake. This difficulty is overcome by the procedure of giving the alcohol in dilute solution by slow rectal injection during sleep and allowing the subject to continue sleeping 4 or more hours after the injection has been completed. It is possible that some very self-observant subject will be able to note the difference between the control and alcohol experiments on waking 5 hours after the introduction of the liquid, but it is much more probable that the processes of adaptation are such that control and alcohol experiments can not be accurately identified by any subjective sensations or impressions. It can not be stated, of course, that the effect of administering a certain amount of alcohol in a certain dilution by rectum is the same in intensity on the various processes measured as when the alcohol is given by mouth. Probably the effects are not of the same intensity, for, judging from the data at hand, they are rather more prolonged and pronounced when the alcohol has been given by rectum.

In studies with animals, alcohol absorption seems to take place in the colon[a] even more readily than in the stomach. Pringsheim[b] concluded that for non-habituated subjects alcohol given by way of the stomach is mostly burned in the liver. It is probable that when given by rectum more of the alcohol escapes the liver and remains to exert an influence on other tissues, and when the introduction is made during sleep there is, doubtless, as a result of decrease in muscular activity,[c] if for no other reason, a general decrease in the rate of utilization. These factors may account for the prolonged influence observed in our experiments. Dr. Carpenter's full report[d] on the rectal feeding of alcohol and other substances will certainly throw light on this problem. He determined the alcohol concentration in the morning urines following the rectal injection and found it high even at the end of the experiment, but his data can not be considered here.

In general, it may be said that this series of psychological measurements, made somewhat more than 6 hours after the completion of the rectal injection of 37.5 grams of ethyl alcohol in a 7.5 per cent by weight solution, shows a positive effect of alcohol which is clearly in the direction of a depressant action, and that these effects agree as to direction with other results obtained by the feeding of alcohol by mouth.[e] Carpenter's method of rectal injection during sleep as an experimental procedure for perfectly masking the introduction of alcohol into the human system is strongly to be recommended.

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[a] Hanzlik and Collins, Journ. Pharmacol. and Exp. Therapeutics, 1913–14, **5**, p. 185.

[b] Pringsheim, Biochem. Zeitschr., 1908, **12**, p. 143.

[c] Gréhant, Compt. rend. Soc. biol., 1903, **55**, p. 802. See also, Völtz and Baudrexel, Arch. f. d. ges. Physiol., 1911, **142**, p. 47.

[d] Carpenter, Am. Journ. Physiol., 1917, **42**, p. 605. This is only an abstract; the full report has not yet appeared.

[e] The question whether alcohol taken at night exerts an influence on the working ability the next day and if there is an accumulative effect from day to day has been the subject of recent investigation. The work of Smith (Bericht über den V. internat. Kongress gegen d. Alkoholismus. Basel, 1895, S. 341) has been followed by the researches of Tötterman (Finska Läkaresallskapets Handlingar, 1916, **58**, p. 1527), Frank (Psychologische Arbeiten, Kraepelin, 1923, **8**, p. 22), and Tigerstedt, C., and Kallioinen (Skand. Arch. f. Physiol., 1923, **43**, p. 87). In all of these investigations alcohol effects are reported to be present the morning following the ingestion.

STANDARD ELECTROCARDIOGRAMS DURING SLEEP AND AFTER RECTAL INJECTION OF ALCOHOL.

As shown in table 34 and stated in the previous discussion of the rectal feeding experiments, standard electrocardiograms were taken at frequent intervals (about 1 hour apart) during the night, while the metabolism experiments were in progress. The electrocardiograms were usually made at the end of alternate metabolism periods. The metabolism experiments were on the third floor of the Nutrition Laboratory, while the electrocardiographic outfit was on the first floor. Communication was by telephone, and usually the ventilating fan and pump of the clinical respiration apparatus were stopped for the short period during which the electrocardiograms were taken.

The electrodes were non-polarizable and of the wick type. A large amount of gauze was loosely wound around the two wrists and left ankle. Each gauze bandage was moistened in salt solution and covered by a loose rubber sleeve to keep the moisture from soaking into the bedding. A heavy wick of moistened gauze, about 2½ feet long and inclosed in thin rubber tubing, connected each bandage to a vessel of salt solution. In these three vessels, which were of ample size, were porous clay cups containing zinc sulphate and amalgamated zinc electrodes, connecting with the string galvanometer. The jars of solution for the non-polarizable electrodes were located under and at the sides of the bed-springs in the respiration chamber, where they would not be disturbed by the subject's movements. The length of tubing between the wrists and the vessels of salt solution was sufficient to allow the subject comfortable change of position. The connections to the string galvanometer had to pass out through the water-seal and thus under the lid of the respiration chamber. There were some difficulties to be overcome, mostly due to induction current from electric motors used with the respiration apparatus, but these could be obviated by stopping the motors for the brief interval in which the actual tracings were made. Usually the skin resistance was not high and the subject was comfortable throughout the night.

The electrocardiographic outfit used was the American model designed by Professor Horatio B. Williams. The magnification was 600 times; the standardization with the subject in series was such that 1 millivolt produced 1 centimeter of deflection at the camera. The tracings were taken directly on bromide paper with time ordinates of 0.04 second. The electrocardiograms for this subject appear to be normal in every way and there is no need to reproduce any of them. Records were made from all three leads, but, as is usual in considering the general time relations of the electrocardiogram, only the tracings for lead II have been used as a basis of discussion.[a] Lead II of course gives the largest deflections, and is thus the most easy of measurement, but for our purpose it has also the very important advantage that it is modified least by slight changes in the subject's recumbent position.

Five complete heart-cycles were measured on each electrocardiographic tracing of lead II, and the average for these five cycles was taken as the result for that particular hour and night. The measurements made were: (1) The duration of the heart-cycle, i. e., from *P* to *P*. This includes the conduction time, the ventricular systole, and the diastole. (2) The conduction time, *P* to *R* or *P* to *Q* if the latter negative deflection appears. (3) The ventricular systole from the beginning of *R* to the end of *T*. (4) The height of *R* above the base between *R* and *T*. (5) The height of *T* above the base between *R* and *T*. The measurements were made under magnification. In the case of the three time measurements, the various points on the tracings were carefully pricked with a fine needle before the measurement scale was applied.

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[a] Lewis, The mechanism of the heart-beat, London, 1911, p. 21; Bazett, Heart, 1918–1920, 7, p. 353.

The string galvanometer could not be used on the night of March 2–3, which was an alcohol experiment. Thus our results are for three control experiments and but two alcohol experiments. For a simplified comparison as to the effect of the alcohol on the electrocardiogram, the records had to be grouped in reference to the different phases of the all-night experiments. From 8 to 14 sets of electrocardiograms were made each night. On four of the nights the number was 10 or more. Usually two or three sets were made during the period after the subject had entered the chamber and after the beginning of the metabolism experiment but before the rectal feeding. This period was about 2 hours in length and the subject was sleeping. The period of rectal injection covered nearly 2 hours and two or more sets of electrocardiograms were made during this interval. Four or five sets were made in the 4 hours following the completed rectal injection and preceding the waking period, and one and sometimes two sets were made during the waking period, which approximately represents the fifth hour after rectal injection.

The data for each of these periods have been averaged separately for the three control days and the two alcohol days. The parallel values under these various phases of the all-night experiments are given in table 36. The duration of the time intervals of the electrocardiograms is given in 0.001 second. It happens that the duration of the heart-cycle was somewhat longer before the injection in the alcohol experiments than in the control experiments. The two average values are 0.934 and 0.884 second. So far as is known, both values are equally normal, as the alcohol had not been introduced and was not a factor which influenced any of the values given in the column headed "before injection." The duration of the heart-cycle during the period of injection is closely the same for both control and alcohol experiments, but shorter than in the period before injection and particularly so in case of the alcohol experiments. In the 4-hour period following injection, and in the fifth hour when the subject was awake, the alcohol values are considerably shorter than the control values when compared directly, without reference to the point at which they started in the early part of the night.

The value for the period before injection may be subtracted from the other values during and following injection with both the control and the alcohol data. From these differences the percentage effect of the alcohol may be computed. (See p. 114.) It is found by this method of computation that the length of the heart-cycle was invariably shortened after the alcohol. In terms of per cent, the effect of the alcohol is −5.6 per cent for the period during injection, −17.0 per cent for the 4-hour period after injection, while the subject was still sleeping, and −13.4 per cent for the fifth hour after injection, when the subject was awake and the metabolism was being measured by the gasometer method. The shorter length of the heart-cycle thus found from the standard electrocardiograms taken during the metabolism measurements is in agreement with the results obtained for the electrocardiograms taken in connection with the psychological work (see table 35), but of course the two groups of results do not cover the same period.

TABLE 36.—*Effect on the electrocardiogram of ethyl alcohol given by rectal injection during sleep.*

Measurement and type of data.	Subject sleeping.			Awake.
	Before injection.	During injection.	4-hour period following injection.	Fifth hour after injection.
Electrocardiograms, lead II:				
Heart-cycle duration in 0.001 sec.:				
Control	0.884	0.862	0.901	0.815
Alcohol	0.934	0.861	0.796	0.743
Alcohol effect in per cent		− 5.6	−17.0	−13.4
P−R time in 0.001 sec.:				
Control	0.159	0.159	0.161	0.157
Alcohol	0.161	0.170	0.161	0.146
Alcohol effect in per cent		+ 5.6	− 1.3	− 8.1
R−T time in 0.001 sec.:				
Control	0.378	0.370	0.372	0.358
Alcohol	0.389	0.372	0.357	0.346
Alcohol effect in per cent		− 2.3	− 6.3	− 6.0
Diastolic time in 0.001 sec.:				
Control	0.347	0.333	0.368	0.300
Alcohol	0.384	0.319	0.278	0.251
Alcohol effect in per cent		−13.9	−34.7	−23.5
Height of R wave in mm.:				
Control	12.1	11.4	11.7	12.2
Alcohol	14.8	14.4	12.9	14.0
Alcohol effect in per cent		+ 2.2	−11.1	− 6.7
Height of T wave in mm.:				
Control	5.3	5.0	5.1	5.2
Alcohol	6.3	5.8	4.4	5.7
Alcohol effect in per cent		− 3.4	−29.3	− 8.6
Pulse-rate per minute:				
Control	68.3	69.6	70.1	77.0
Alcohol	63.9	69.9	74.5	82.4
Alcohol effect in per cent		+ 7.1	+13.3	+14.8
Oxygen consumption per minute in c. c.:				
Control	202	205	206	232
Alcohol	198	206	222	237
Alcohol effect in per cent		+ 2.5	+10.0	+ 4.5

More to the point is the comparison with the pulse-rate per minute from counts with the stethoscope which was resting over the subject's heart all night. Dr. Carpenter has kindly permitted the use of these data obtained in his experiments, and they are given at the bottom of table 36. The first average preliminary pulse-rate for the control data is 68.3 beats per minute. This would correspond to a pulse-cycle duration of about 0.88 second. The first value in the alcohol data is 63.9 beats per minute, which would correspond to a heart-cycle length of about 0.94 second. The agreement between the data taken as pulse-rate per minute and as standard electrocardiograms is thus extremely close for the period prior to rectal injection. From Dr. Carpenter's data for the pulse-rate per minute of this subject in the two alcohol and three control experiments, the effect of the alcohol is found to be +7.1 per cent in the period during injection, +13.3 per cent in the 4-hour period following injection with the subject asleep, and +14.8 per cent in the fifth hour after injection in the morning with the subject awake. A plus alcohol effect in results given as pulse-rate per minute is equivalent to a minus alcohol effect in results given as heart-cycle duration. The two groups of values for the percentage effect of alcohol are not absolutely the same, but substantially of the same magnitude, and demonstrate a very definite increase in pulse-rate associated with the rectal injection of 37.5 grams of alcohol in a dilute solution.

In many publications from the Nutrition Laboratory, Dr. Benedict has shown that there is a close parallelism between fluctuations in pulse-rate and fluctuations in metabolism, the higher metabolism nearly always being associated with increased pulse-rate.[a] At the bottom of table 36, further data are contributed from Dr. Carpenter's results for the oxygen consumption, which are grouped in the same way as those for the pulse-rate. From these figures it is seen in the first place that the oxygen consumption per minute in the period before injection is less in the alcohol than in the control experiments, as was also found for the pulse-rate per minute. This is in agreement with the pulse-metabolism relationship usually observed. Similar agreements are obvious in the other periods of the experiment, that is, during and following the injection. As the pulse-rate was increased after alcohol, so it is found that the oxygen consumption is also increased. The values are, however, not so large with the latter, being +2.5 per cent, +10.0 per cent, and +4.5 per cent for the period during injection, 4 hours following injection, and the fifth hour after injection. This last value (4.5 per cent) is somewhat out of line by being so small when the pulse change was 14.8 per cent.[b]

The conduction time, which is the interval from the beginning of the *P* deflection to the beginning of *Q*, if it exists, otherwise to the beginning of *R*, is for this subject approximately 0.16 second. It was longer in the preliminary period of the alcohol experiment than in the preliminary period of the control experiment, as was likewise found for the duration of the heart-cycle and for the pulse-rate per minute. The conduction time is undoubtedly longer during the rectal feeding period on both alcohol nights. On March 23 to 24, when 14 sets of electrocardiograms were taken during the night, it happened that four of these sets were recorded during the actual rectal feeding. The *PR* period averages for these four sets are, respectively, 0.162, 0.167, 0.167, and 0.165 second, with an average of 0.165 second. On February 15-16, 11 sets of electrocardiograms were taken during the night and 2 of them came during the rectal feeding period. The *PR* interval in these two cases is 0.175 and 0.172 second. Soon after the feeding period was completed on this night, the *PR* interval changes to 0.168, then 0.161, and 0.149 second. The *PR* interval therefore during rectal injection shows an alcohol effect in the direction of a lengthening, amounting to +5.6 per cent. In the 4-hour period following injection it is shortened, the alcohol effect being −1.3 per cent. When the subject is awake in the fifth hour after alcohol the conduction time is more conspicuously shortened, with an alcohol effect of −8.1 per cent.

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[a] Benedict, Carnegie Inst. Wash. Pub. No. 77, 1907, p. 488, and later publications of this Institution.

[b] Carpenter, Am. Journ. Physiol., 1917, 42, p. 605, reports that in a few of his experiments the oxygen consumption was raised about 10 per cent, and the pulse-rate increased 3 to 5 beats per minute.

The duration of ventricular systole, as measured from the beginning of *Q*, if it exists, otherwise from the beginning of *R* to the end of *T*, is in this case about 0.37 second when the subject is asleep and somewhat shorter when awake. The average *RT* time is longer in the preliminary period of the alcohol days than in that for the control days. As was found with the duration of the complete heart-cycle, the alcohol effect is fairly large. The *RT* time is shortened after alcohol in the period during injection by 2.3 per cent. Following injection but during sleep, the shortening was 6.3 per cent and in the waking period in the morning, 6.0 per cent. In no case is the decrease in the *RT* interval so large after alcohol as that obtained for the duration of the heart-cycle. The effect upon the duration of the whole heart-cycle is a composite of the effect on the various factors which constitute the total cycle.

The alcohol effect on the diastolic time is also given separately in table 36. These data have the same general characteristics as those for the duration of the heart-cycle, except that there is a greater difference between alcohol and control values during the period of injection. The alcohol effect on the diastole is larger than with any other factor in the table. During injection the diastole is reduced in time by 13.9 per cent; in the 4-hour period following injection it is shortened by 34.7 per cent, and in the fifth hour after injection, with the subject awake, the effect is −23.5 per cent. The shortening of the diastole by the alcohol is therefore approximately four times as great as the shortening of the ventricular systole. These results confirm the rather tentative conclusions reached by Hunt[a] and Dodge and Benedict[b] that the ethyl alcohol produces its effect of an increased pulse-rate primarily through its depressant action on the cardio-inhibitory center. It seems justifiable in other discussions of increased pulse-rate after alcohol reported in this volume to speak of this alcohol effect as a depressant action, since shortening of the diastole without much change in systole is the characteristic symptom of loss of vagus tone.

Both the *R* and the *T* waves of the electrical complex lend themselves readily to the measurements of height, and data in terms of millimeters are included in our table of results for the effect of alcohol on the electrocardiograms. The *R* deflection usually extended about 12 mm. above the base-line between *R* and *T*. It was positively larger in the preliminary period for the alcohol data, just as we have seen that the pulse-rate was slower in this period than in the comparison period for the control data. The alcohol effect is a slight increase in the height of *R* during injection amounting to 2.2 per cent, a decrease of 11.1 per cent in the 4-hour period after injection, and a decrease of 6.7 per cent in the fifth hour after injection while the subject was awake. The height of the *T* deflection above the base-line between *R* and *T* is about 5 mm. This is also larger in the preliminary period before the alcohol injection than before the control solution. The alcohol effect appears to be fairly prominent and concordant in all periods, being in order −3.4, −29.3, and −8.6 per cent.

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[a] Hunt, Am. Journ. Physiol., 1899, 2, p. 395.

[b] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 235.

The only other direct study of the effects of alcohol on the normal electrocardiogram known to the author is that of Galeotti and Di Jario.[a] They gave about 50 c. c. of ethyl alcohol in the form of cognac to 13 male subjects, some of whom took considerably larger amounts than this. The alcohol was taken on an empty stomach or after a small meal. A normal electrocardiogram was secured before the alcohol was taken and then other such tracings were made at various intervals following the alcohol. Usually two tracings were taken after the alcohol, one about 15 minutes and the other 40 to 80 minutes afterwards. Apparently there were no control experiments and the results are not sufficiently concordant within themselves to allow one to make a satisfactory comparison, although they had several subjects. They made one experiment with each man, so far as the published results indicate. Their preliminary pulse-rates were apparently high, ranging from 66 to 96 beats, and averaging 77 beats per minute. They state that when the preliminary pulse-rate was high the alcohol effect was in the direction of a retardation, and that when the preliminary rate was low the alcohol produced an increase in pulse frequency. In the 13 experiments there were 8 cases of a decrease in pulse-rate after the alcohol. The authors note that this decrease corresponds with the results of Swientowski.[b] In 5 cases the heart-rate was accelerated. Of course, no very definite information, particularly with reference to the effect of the alcohol, can be had from studies in which there were no control experiments and in which, as a rule, each subject is used but once and for a rather brief period. However, it seems incumbent to point out any disagreements or agreements found between one's own results and such published data as he is able to discover, particularly when the procedure is somewhat elaborate and but few have undertaken like studies. Galeotti and Di Jario usually found an increase in the height of the deflection, just as they found usually a decrease in the heart-rate.

To summarize, when alcohol was given by rectal injection, the electrocardiogram shows no striking change in character. The length of the heart-cycle is definitely shortened. Both the systole and diastole are shortened, the effect of the alcohol on the diastole being approximately four times as great as the effect on the systole. With the increase in pulse-rate or a decrease in the duration of the heart-cycle that follows the rectal injection of 37.5 grams of alcohol, there is apparently a decrease in the amplitude of the chief electrical deflections which constitute the electrocardiogram. This decrease in the period following the completed injection of the alcohol may be from 10 to 20 per cent. The procedure of rectal injection of dilute alcohol during sleep can be recommended as a method for the study of the effects of ethyl alcohol on the metabolism and circulatory phenomena. A direct comparison between the results when the alcohol is given by mouth and by rectum remains to be made, as at present the effective intensity in alcohol dosage from the two methods of introduction is not known.

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[a] Galeotti and Di Jario, Arch. di Fisiol. 1914, 12, p. 401.

[b] Swientowski, Zeitschr. f. klin. Med., 1902, 46, p. 284.

CHAPTER V.

EFFECT OF DILUTE ALCOHOLIC BEVERAGES ON A TRAINED SUBJECT.

The question has often been raised whether equivalent amounts of alcohol exercise equivalent neuro-muscular effects, regardless of whether the alcohol is taken in the form of regular spirits, wine, or light beer. Vast quantities of dilute alcoholic beverages have been regularly consumed in most of the large civilized countries of the world, and these dilute beverages, especially light wines, ale, and beer, have popularly been supposed to be non-intoxicating. Certain European governments have in the past allowed beverages containing about 2 per cent of alcohol by weight to go tax-free. When the question of the toxic or non-toxic action of beverages containing less than 3 per cent by weight was recently before the courts of the United States, there was available hardly any direct objective evidence. Even such evidence as was offered had lately been produced more or less at the instance of one or the other of the parties involved in the dispute.

The question of whether alcohol taken in very dilute form, for example, 2.75 per cent solution by weight, exerts a measurable effect upon neuro-muscular efficiency as determined under laboratory conditions is of two-fold importance. In the first place, as a scientific question, the answer will contribute to the understanding of the mechanism through which alcohol exerts its influence on the nervous system, since it seems probably true that the dilution in the beverage is similar to the dilution of the alcohol by the contents of the stomach. Secondly, the problem is one of practical interest, since the vast majority of the individuals throughout the world who use alcohol take it in rather dilute forms.

ABSORPTION OF ALCOHOL FOLLOWING INGESTION.

In some preceding experiments reported in this monograph, when a meal was ingested not simultaneously with the alcohol, but about 45 minutes before the taking of the dose, the effect of the beverage on typewriting and other performances of our subjects was markedly less. In both instances, i. e., with and without food, the same amount of alcohol was taken. It is not simply the presence of alcohol in the stomach which causes it to exert its characteristic effect on the nervous system. The alcohol must be absorbed through the walls of the alimentary tract and find its way into the blood-stream before it can exert a depressant action. As a usual thing, the subjective effects begin to be noticed 10 to 20 minutes (sometimes earlier) after the alcohol has been ingested. If, in place of giving the alcohol by mouth, it is injected directly into the blood-stream, as was done by Gabbe,[a] the toxic effects are immediately experienced.

From a number of researches, mostly on animals but some on human subjects, it is known that after a single large dose the alcohol appears unchanged in the blood and the amount in the blood-stream gradually increases to a maximum near which it remains for one or more hours.

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[a] **Gabbe, Deutsch. Arch. f. klin. Med., 1917, 122, p. 81.**

This stage is designated as "the Gréhant plateau."[a] Following this plateau, the alcohol concentration in the blood slowly decreases, but the substance does not completely disappear for several hours. The concentration curve for alcohol in the blood after such an experiment depends on the amount which has been taken in terms of body-weight, the rate at which the alcohol has been metabolized, as well as on factors which influence absorption.

As a general thing, studies which have related to absorption, the concentration of alcohol in the blood, in body tissues, etc., have almost wholly neglected the question of the effect of alcohol on the central nervous system. Probably for the most part this has been because animals were used in the experimentation. On the other hand, the studies more typically psychological have grossly neglected consideration of the differences in absorption, the influence of food, the concentration of alcohol appearing in blood and urine, the amount of alcohol excreted, the effect of exercise on the rate at which the alcohol disappears from the body, and similar factors. In reports of alcohol investigations and in the reviews of such reports the statement is commonly made that wide individual differences are found in the effects of alcohol on the various subjects that have been employed. These individual differences seem never to have been satisfactorily analyzed. Usually the suggestions offered are in reference to tolerance or susceptibility for alcohol, and always on the assumption that since each man received essentially the same dose, they were all subjected to the same influence. It may be that the individual differences are such that they can not be easily analyzed. However, if it can be demonstrated that two subjects reacting differently to alcohol actually absorb it in substantially the same way, with the result that after a given dose the alcohol reaches the same maximum concentration in the blood-stream, and so with both subjects there are equal opportunities for the alcohol to affect the nerve centers, then we are dealing with a more definite individual difference and one that is more nearly describable. As long as the factor of absorption is totally neglected and unknown, the other data must suffer from considerable vagueness in respect to the real intensity of dosage.

It is not convenient to pump the stomach periodically and thus determine the rate of absorption of the alcohol by recovering that which is unabsorbed, nor is it conducive to the best performance in psychological tests, at least for the usual subjects, to have frequent blood samples taken from an arm vein. Fortunately, alcohol, after it is absorbed through the walls of the alimentary tract, not only appears in the blood but also in other body fluids, including the urine. It has been claimed by Nicloux and Nowicka,[b] Widmark,[c] Ambard,[d] and others that the alcohol concentration in the urine excreted at short intervals agrees very nearly or completely with the percentage of alcohol in a blood sample taken at the same time, and therefore that a knowledge of the alcohol content of the blood-stream, which content represents the combination of the factors of absorption and utilization, may be obtained from the urine samples.

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[a] Gréhant, Comp. rend. Soc. biol., 1899, **51**, p. 946; Gréhant, Comp. rend. Soc. biol., 1903, **55**, p. 1264; and Widmark, Acta Medica Scand., 1919, **52**, p. 87.

[b] Nicloux and Nowicka, Journ. de Physiol. et de Pathol. gén., 1913, **15**, p. 297.

[c] Widmark, Upsala Läkareförenings Förhandlingar, 1914, **19**, p. 241; also Skand. Arch. f. Physiol., 1916, **33**, p. 85.

[d] Ambard, Physiologie Normale et Pathologique des Reins. Paris, 2d ed., 1920; see, also, some work done under the direction of Professor Ambard by Chabanier and Ibarra-Loring, Comp. rend. Soc. biol., Paris, 1916, **79**, p. 8.

Certain other workers, Gréhant[a] and particularly Schweisheimer,[b] have put forward the conclusion that the intensity of the alcohol effect is directly dependent upon the alcohol concentration in the blood. Schweisheimer asserts that this fact, first stated by him, could not be proved by experiments with animals, but that his work with men, who were abstinents, moderate drinkers, and habituals, absolutely proved that the intoxication is "exactly parallel in its increase and decrease with the rising and the sinking of the alcohol content of the blood." In the experiments on which Schweisheimer bases his conclusion, he gave the subjects about 1.55 c. c., of absolute alcohol per kilogram of body-weight. He worked with adults, and hence usually more than 100 c. c. of absolute ethyl alcohol was given in the form of wine containing 10 per cent. His subjects were kept in bed during the experiment for uniformity in muscular exercise. He took blood samples, but gave the men no other tests. They were questioned as to their feelings of dizziness or nausea, but seemingly the opportunity for directly observing and estimating the degree of intoxication must have been quite limited, due to the recumbent position and quietness of the subjects. It is thus possible that his positive statements are unwarranted. In the more recent work of Mellanby[c] it was found with dogs that the alcohol effects do not seem to be directly parallel to the alcohol concentration in the blood, but begin to decrease after the alcohol has reached the maximum in the blood and before it has decreased in the same proportion.

To correlate the change in course and level of the concentration curve of alcohol in the body fluids with the intensity of physiological and psychological effects appears highly desirable. Hitherto our attention has been given principally to the effect following the ingestion of the alcohol. It has been noted that there is a time when the influence of the alcohol on the neuro-muscular system reaches its maximum, after which point the effects begin to disappear. On the causal side, what was happening to the alcohol and what changes were taking place in the blood-stream have usually been thought, if considered at all, beyond the province of the psychological investigation, but obviously the two sides are closely related as cause and effect and should, if possible, be studied synchronously. From such a combined study we may confidently expect to learn more about the nature and perhaps the mechanism of the alcohol effect on the central nervous system. Such problems as individual differences, alcohol tolerance, the relative effects of different alcoholic beverages, and different concentrations of beverages can be hopefully attacked from this point of view with a combination of biochemical and psychological techniques.

Ethyl alcohol as a substance which exercises an influence on the central nervous system is peculiarly open to study in this way. It is readily absorbed, both from the stomach and from the intestines, as well as from the colon.[a] As is well known, the processes of digestion do not affect alcohol, and it therefore appears unchanged in the blood and tissues of the body. With the exception of the small percentage which is given off in the breath and through the urine,[b] all of the alcohol ingested is metabolized. This process of utilization begins as soon as absorption commences and, so far as research has shown, continues uninterruptedly as long as any alcohol is present in the system. If the alcohol contents of the blood and of the urine are identical for samples taken in short periods and at the same time, as stated by Widmark and others, then from urine samples alone the alcohol concentration curve for the blood may be determined. Frequent blood samples of 20 c. c. are certain to disturb the psychological measurements for a number of subjects, but nothing could be simpler than the routine of collecting urine samples every 20 or 30 minutes throughout an experimental session.

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[a] Gréhant, Comp. rend. Soc. biol., 1903, **55**, p. 1264.

[b] Schweisheimer, Deutsch. Arch. f. klin. Med., 1913, **109**, p. 271.

[c] Mellanby, Med. Research Com., Sp. Rept. Ser. No. 31, 1919; see, also, British Journ. Inebriety, 1920, **17**, p. 157.

In all the experiments reported in this chapter, urine samples were regularly taken for the purpose of comparing the intensity and temporal incidence of the alcohol effect with the alcohol concentration. Results for samples collected in 1919 are fragmentary, due to the fact that the urines were kept too long before analysis, which was made by the Nicloux method. The 1920 experiments, and those with 15-minute periods, all provide comparisons of this nature. A few blood samples were also taken with *Mow,* but are not discussed here, as they were simply preliminary to a study of the concentration of alcohol in the blood in comparison with its ingestion which was later made with a group of young men. (See p. 211.) A general discussion of the concentration of alcohol in the blood and urine is given in Chapter VII. (See p. 261.)

GENERAL DETAILS OF STUDY WITH TRAINED SUBJECT.

The influence of dilution on the effect of alcohol was the particular problem studied in the experiments reported in this chapter. All of the alcohol results discussed in the earlier pages (except with rectal feeding) were obtained when the dosage was given in a strong solution, ranging from 14 to 22 per cent by weight. This is, of course, much higher than the percentage content of light wines and beers which have been popularly used. It has generally been contended that the alcohol effect might disappear, or at least be very much reduced, if ethyl alcohol were given in a very weak solution. In attacking the problem, it was deemed economical to experiment first with a subject who had received a large amount of practice in the particular measurements which were to be used as indicators, so that the extraneous factor of learning and habituation to the routine would be as small as possible. It was also thought that special emphasis should be given to tests of motor control, since coordination tests in the study of Dodge and Benedict and in our later investigations had shown the typical alcohol effect regularly. As a result of developments in connection with the low-diet investigation[c] and a series of unpublished measurements made on aviation recruits, a number of psychological techniques had been developed at the Nutrition Laboratory, and these were put into condition for use in this research on the effect of alcohol given in dilute form.

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[a] See forthcoming studies by my colleague, Dr. Thorne M. Carpenter.

[b] Miles, Journ. Pharm. and Exp. Therapeutics, 1922, 20, p. 305. Usually less than 2 per cent of the ingested alcohol was given off in the urine within 2 hours after it was taken.

[c] Benedict, Miles, Roth, and Smith, Carnegie Inst. Wash. Pub. No. 280, 1919.

The subject, *Mow,* who served in all of these experiments, is a man about 36 years of age, of medium build, with a height of 178 cm., and nude body-weight of 70 kg.[a] In reference to alcohol, he is abstinent by habit, but had no objection to the experimental routine. It is believed that he is without prejudice in reference to the alcohol problem and takes an objective attitude in reference to such data. He had undergone a great number of preliminary trials of one sort or another and had assisted in the development of much of the apparatus. It was, however, easily possible for him to leave the conduct of the tests entirely to the technician giving them and to confine himself strictly to the attitude of a subject only. *Mow* had received considerable psychological training as an observer.

It must be recognized that *Mow* always knew when alcohol was taken, that is, he knew objectively as well as subjectively. It has been contended throughout this report that the subjective information that alcohol has been taken is almost always a certainty if the alcohol has been given by mouth and if the subject has any ability whatsoever in self-observation. *Mow* never knew any of the results of the test on the days when he was serving as subject, and had no information as to how well or how poorly he was doing on any group of days. The data were in no wise put together to contrast control and alcohol performances until a particular group of experiments had been completed.

The alcohol dosage chosen for these experiments with dilute solutions was 27.5 grams or 34.4 c. c. of absolute ethyl alcohol. The solution of grain alcohol from which our experimental beverages was invariably made up had a density of 0.81453, which corresponds to 91.282 per cent by weight. To secure 27.5 grams of absolute alcohol it is thus necessary to take 37 c. c. of the solution. This amount was always, in these experiments, diluted to a total volume of 1,000 c. c. The dilution, at times, was made with different substances, but the total amount was always 1 liter containing 2.75 per cent of alcohol by weight. This weight of alcohol corresponds closely to dose A of the typewriting series described in Chapter II and amounts to approximately 0.5 c. c. of absolute alcohol per kilogram of body-weight, which is also about the same proportion of dosage to body-weight as was used in some of the typewriting experiments.

The chronological arrangement of the 70 experiments on *Mow*, with the pertinent details as to dosage and other matters, is given in table 37. It will be seen that the experiments extended over a period from November 1919 to April 1921. There was, however, a break of nearly a year, from December 20, 1919, to December 7, 1920. Of the 70 experiments, 44 were with alcohol and 26 without. In every experiment, however, at least 1 liter of liquid was ingested. As the alcohol dose varied in reference to the substance in which it was diluted, so the control dose varied also, the latter being a duplicate of the alcohol dose in each case, except that it did not contain the 27.5 grams of alcohol. Both control and alcohol doses were

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[a] The subject in this case was the writer. There are obvious advantages in such an arrangement if the tests are all given and the results recorded by a competent assistant.

TABLE 37.—*Chronological arrangement of experiments with dilute alcohol with subject Mow.*

No. of experiment.	Date.	Type and series of experiment.	Total volume of dose.	Alcohol by weight.		Number of periods.	Duration of periods.[1]
				Amount.	Concentration.		
	1919.		*c. c.*	*gms.*	*p. ct.*		*min.*
[2]1	Nov. 4	Control, water	1,000	....	....	3	30
2	Nov. 5	....Do	1,000	....	....	5	30
3	Nov. 6	Alcohol, water	1,000	27.5	2.75	5	30
4	Nov. 7	....Do	1,000	27.5	2.75	5	30
5	Nov. 8	Control, water	1,000	....	....	5	30
6	Nov. 10	Alcohol, water	1,000	27.5	2.75	6	30
[3]7	Nov. 12	Control, water	1,000	....	....	5	30
[4]8	Nov. 17	Alcohol, water	1,000	27.5	2.75	5	30
[4]9	Nov. 18	....Do	1,000	27.5	2.75	5	30
[4]10	Nov. 19	Control, water	1,000	....	....	5	30
[4]11	Nov. 20	Alcohol, 490 c. c. loganberry juice	1,000	27.5	2.75	5	30
[4]12	Nov. 21	Control, water	1,000	....	....	5	30
[4]13	Nov. 22	....Do	1,000	....	....	5	30
[4]14	Nov. 25	Alcohol, water	[5]1,000	27.5	2.75	5	30
[4]15	Nov. 26	Control, water	[5]1,000	....	....	5	30
[4]16	Dec. 1	Alcohol, 300 c. c. grape juice[6]	1,000	27.5	2.75	6	30
[4]17	Dec. 2	Control, 300 c. c. grape juice	1,000	....	....	6	30
[4]18	Dec. 3	Alcohol, 830 c. c. beer[7]	1,000	27.5	2.75	6	30
[4]19	Dec. 4	Control, 830 c. c. beer	1,000	....	....	6	30
[4]20	Dec. 5	....Do	1,000	....	....	6	30
[4]21	Dec. 8	Alcohol, 830 c. c. beer	1,000	27.5	2.75	6	30
[4]22	Dec. 9	....Do	1,000	27.5	2.75	6	30
[4]23	Dec. 10	Control, 830 c. c. beer	1,000	....	....	6	30
[4]24	Dec. 11	....Do	1,000	....	....	6	30
[4]25	Dec. 13	Alcohol, 830 c. c. beer	1,000	27.5	2.75	6	30
[4]26	Dec. 15	Alcohol, 300 c. c. grape juice	1,000	27.5	2.75	6	30
[4]27	Dec. 16	Control, 300 c. c. grape juice	1,000	....	....	6	30
[4]28	Dec. 17	Alcohol, 300 c. c. grape juice	1,000	27.5	2.75	6	30
[4]29	Dec. 18	....Do	1,000	27.5	2.75	6	30
[4]30	Dec. 20	Control, 300 c. c. grape juice	1,000	....	....	6	30
	1920.						
[2]31	Dec. 7	....Do	1,000	....	....	6	30
32	Dec. 8	....Do	1,000	....	....	6	30
33	Dec. 9	Alcohol, 300 c. c. grape juice	1,000	27.5	2.75	6	30
34	Dec. 10	....Do	1,000	27.5	2.75	6	30
35	Dec. 11	Control, 300 c. c. grape juice	1,000	....	....	6	30
36	Dec. 13	Alcohol, 500 c. c. cider	1,000	27.5	2.75	6	30
37	Dec. 15	Control, 500 c. c. cider	1,000	....	....	6	30
38	Dec. 16	Alcohol, 500 c. c. cider[8]	1,000	34.0	3.40	6	30
39	Dec. 17	....Do	1,000	27.5	2.75	6	30
40	Dec. 18	Control, 500 c. c. cider	1,000	....	....	6	30
41	Dec. 20	Alcohol, 500 c. c. cider[8]	1,000	28.8	2.88	6	30
42	Dec. 22	Control, 500 c. c. cider	1,000	....	....	6	30
43	Dec. 28	Alcohol, 300 c. c. grape juice	1,000	27.5	2.75	[9]16	[9]15
44	Dec. 29	Alcohol, 600 c. c. grape juice	[10]2,000	55.0	2.75	16	15
45	Dec. 30	Alcohol, 300 c. c. grape juice[11]	1,000	27.5	2.75	16	15
46	Dec. 31	....Do.[12]	1,000	27.5	2.75	16	15
	1921.						
47	Jan. 4	....Do.[13]	1,000	27.5	2.75	16	15
48	Jan. 7	....Do.[14]	1,000	27.5	2.75	16	15
49	Jan. 25	....Do.[13]	1,000	27.5	2.75	16	15
50	Jan. 31	....Do.[14]	1,000	27.5	2.75	16	15
51	Feb. 2	....Do.[11]	1,000	27.5	2.75	16	15
52	Feb. 4	....Do.[15]	1,000	27.5	2.75	16	15
53	Feb. 7	....Do.[12]	1,000	27.5	2.75	16	15
54	Feb. 8	....Do.[15]	1,000	27.5	2.75	16	15

TABLE 37.—*Chronological arrangement of experiments with dilute alcohol with subject Mow*—Continued.

No. of experiment.	Date.	Type and series of experiment.	Total volume of dose.	Alcohol by weight.		Number of periods.	Duration of periods.[1]
				Amount.	Concentration.		
	1921.		*c. c.*	*gms.*	*p. ct.*		*min.*
55	Feb. 9	Control, 300 c. c. grape juice	1,000			16	15
56	Feb. 10	....Do	1,000			16	15
57	Feb. 14	....Do	1,000			16	15
58	Feb. 15	Alcohol, 300 c. c. grape juice	1,000	27.5	2.75	16	15
59	Feb. 17	....Do	[16]1,000	27.5	2.75	16	15
60	Feb. 23	Alcohol, 570 c. c. grape juice	[17]1,900	52.2	2.75	16	15
61	Feb. 24	Alcohol, 300 c. c. grape juice	[16]1,000	27.5	2.75	16	15
62	Feb. 28	Alcohol, 570 c. c. grape juice	[17]1,900	52.2	2.75	16	15
63	Mar. 9	Alcohol, 450 c. c. grape juice	[18]1,500	41.0	2.75	16	15
64	Mar. 14	Alcohol, 300 c. c. grape juice	1,000	27.5	2.75	[19]16	15
65	Mar. 15	....Do	1,000	27.5	2.75	[19]16	15
66	Mar. 22	Control, 300 c. c. grape juice	1,000			[19]16	15
67	Mar. 24	....Do	1,000			[19]16	15
68	Apr. 15	Alcohol, 300 c. c. grape juice	1,000	27.5	2.75	[19]16	[20]15
69	Apr. 21	....Do	1,000	27.5	2.75	(21)	[20]15
70	Apr. 28	Alcohol, water[15]	1,000	27.5	2.75	(21)	[20]15

The 30-minute experimental periods included the following measurements: finger movements, code, pursuitmeter, pursuit pendulum, eye movements, eye reactions, station, and visual acuity or electrical threshold. In the 15-minute periods three measurements—pursuit pendulum, eye reactions, and electrical threshold—were omitted. A urine sample was usually taken at the end of each 30-minute and 15-minute period following the dose.

A preliminary practice day.

The subject complained of being chilled during this experiment, so it was discarded before the results were seen.

The regular experiment was followed by metabolism measurements.

The 1-liter dose was taken in two portions: 500 c. c. at 1h15m p.m., end of period 2, and 500 c. c. at 2 p.m., the beginning of period 4.

A common commercial brand of unsweetened grape juice. Analysis showed 0.1 per cent or less of alcohol. The 300 c. c. of grape juice had a food value of about 200 calories. The same brand of grape juice was used throughout the experiments.

A commercial non-alcoholic beer or beer substitute was used throughout which was found to contain 0.4 per cent alcohol by weight. The three bottles regularly used in making up a 1-liter dose were credited with 3 grams of alcohol, and 24.5 grams of alcohol were added with water to make the total volume 1,000 c. c.

The alcohol content of the cider used on this day increased more rapidly than was predicted, which accounts for the larger alcohol dose in this experiment. Ordinary fresh sweet cider was used.

Two periods were preliminary in this and subsequent experiments, hence 14 periods followed the dose. These allow us to observe the alcohol effect for 3½ hours following complete ingestion.

A double dose was taken in this experiment and ingested within 20 minutes.

In addition to the regular dose, 0.5 liter of water was taken 1 hour following the alcohol and grape juice.

One hour following the dose 0.5 liter of whole milk was taken.

One hour before the dose 0.5 liter of water was taken.

One hour before the dose 0.5 liter of whole milk was taken.

Experiment performed between 8 and 12 o'clock in the morning and with subject in post-absorptive condition. All other experiments noted in this table were performed in the afternoon between 12 and 5 o'clock, and about 200 calories of carbohydrate had been taken 2 hours before the dose.

The 1-liter dose was taken in three equal portions separated by half-hour intervals, i. e., at beginning of periods 3, 5, and 7.

One liter of 2.75 per cent alcohol was taken as usual at the end of period 2, then beginning with period 8, a 100 c. c. portion was taken at the beginning of each period. The additional 900 c. c. were thus taken in 9 portions and over a time of 2¼ hours.

After the usual dose, beginning with period 7, a 50 c. c. portion was taken at the beginning of each period.

In place of the usual measurements, the subject worked on a bicycle ergometer during periods 3, 5, 7, 9, 11, 13, and 15.

Blood samples as well as urine samples were taken.

No measurements except blood and urine samples; subject quiet as possible otherwise.

taken at a temperature of 18° to 19° C. Except in those instances when we divided the liter to study the effect of extending the period of ingestion, the dose was regularly taken within 10 minutes or less. This was no hardship, for the subject did not take so much liquid with meals or between meals during those days when the experiments were made. No difficulty was experienced in consuming this liter of liquid.

From the data in the extreme right-hand column of table 37 regarding duration of period, it will be noted that the first 42 experiments were so arranged that each experimental period was 30 minutes in length. These 30-minute experiments will first be discussed. Six of the 42 experiments are not reported: Nos. 1 and 31 were preliminary practice days, No. 7 was discarded at the time of taking the tests as the subject complained much of chilling, No. 11 was irregular in that loganberry juice was used; in No. 14 the alcohol dose was taken in two portions, separated by 1 hour, and the control dose was similarly divided in No. 15.

INFLUENCE OF DILUTE ALCOHOL MEASURED IN 30-MINUTE PERIODS.

Dosage and General Program of Experiments.

The experiments with 30-minute periods divide themselves into five groups or series, which are tabulated chronologically. The *first* series was characterized by the fact that the alcohol was diluted with water only. It comprises 5 control and 5 alcohol days, covering the period from November 5 to 22, 1919. The *second,* or beer-alcohol series, is characterized by the fact that the alcohol was diluted with a commercial "non-alcoholic beer" or beer substitute, which was used throughout these 8 experiments. According to our determinations, the beer contained 0.4 per cent alcohol by weight. The three bottles regularly used in making up a 1-liter dose were credited with 3 grams of alcohol, and only 24.5 grams of alcohol were added, together with some water, to make the total volume of 1,000 c. c. In the control dose, the three bottles of beer were likewise used, and thus on control days the subject received 3 grams of alcohol. There were 4 control experiments and 4 alcohol experiments, all of which were made between December 3 and 13, 1919. In the *third* series, the alcohol was diluted with a common commercial brand of unsweetened grape juice. Analysis shows that there was 0.1 per cent or less of alcohol in the 300 c. c. of grape juice used in making up both the alcohol and the control doses. This quantity of grape juice had a food value of about 200 calories. The same grape juice was used throughout the series, which contains 3 control days and 4 alcohol days. The experiments were made between December 1 and 20, 1919. There was a slight overlapping in time of the grape-juice-alcohol series with the preceding beer-alcohol series. The *fourth* or grape juice and alcohol series of 1920 came just a year later than the first grape juice and alcohol series, with the same dosage and with 2 control and 2 alcohol[a] days. The *fifth* and last series with 30-minute periods may be designated as the cider-alcohol series of 1920. The alcohol was diluted ordinarily with fresh, sweet cider. In two cases, however, experiments Nos. 38 and 41, the alcohol content of the cider used had increased more rapidly than was predicted, which accounts for the larger dose in this case. A sample of the cider was analyzed at the time the dose was used, so that the alcohol content was carefully determined. This last series of experiments contained 7 days—3 control and 4 alcohol days.

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[a] It was unfortunate that the only preliminary practice day was Experiment No. 31 and that others were not arranged to precede this series, also that the series was so short.

These five series of experiments are really repetition experiments on *Mow*, their general purpose being to find whether or not there is a demonstrable effect from taking a liter of liquid containing 2.75 per cent of alcohol. It was thought that the dilution of the alcohol with various commonly-used beverages would provide information as to differences, if any, in the effect of the alcohol under these varying conditions. Repeated experiments with the same subject, with the same experimental conditions and measurements, gave opportunity to observe if an alcohol tolerance developed at all rapidly in connection with such usage.

The conditions which apply to all these five series of observations on *Mow* may be outlined briefly. The experiments were invariably made in the early part of the afternoon. The subject ate a rather hearty breakfast at $7^{h}00^{m}$ to $7^{h}30^{m}$ a. m. The morning was spent in laboratory work of one kind or another, and 1 hour before the preliminary part of the experiment began the subject ate 25 grams of dry crackers and the same weight of strawberry jam. No water was taken at the time or in the two hours preceding the alcohol. At the end of an hour the subject urinated and began his experiment. The series of measurements was carried out twice before the dose was taken, that is, there were two preliminary periods. Sometimes the preliminary experiments began at 12 (noon) and sometimes at 1 p. m. After the two preliminary periods, which always occurred whether the control or the alcohol solution was to be taken afterwards, there was an intermission of 15 minutes. During the first 10 minutes the subject drank the 1-liter dose, either alcohol or control, as the case might be. He then sat down for 5 minutes before resuming the tests. Four experimental periods were next made in succession.

The only exception to this routine was in the water-alcohol series, in which only three experimental periods were completed following the dose. The four periods required almost exactly 2 hours. There was a slight deviation in total time, which probably tended toward a little longer period. The sessions were extended only 2 hours beyond the ingestion of the dose for various reasons, i. e., to minimize fatigue, to economize the time of both subject and assistant, and to give opportunity for subsequent observations of the metabolism and other factors. Furthermore, it had been observed in the typewriting experiments that the maximal effect occurred within the first 2 hours. The subject always urinated at the end of the second preliminary period and also at the end of each period following the experimental dose. In the case of control experiments the volume of the urine only was measured and no sample was retained. For all alcohol experiments not only was the volume of the urine measured, but the sample was kept for determination of the alcohol content of the urine.

The five series of experiments on *Mow* are most regular in respect to preliminary food, controlled conditions of living, the time of day for experimentation, the experimental routine, and exactness of the time intervals succeeding the ingestion of the alcohol. The routine always included the following measurements and in the following order for all the series: finger movements, code test, pursuitmeter, pursuit pendulum, eye movements, eye reactions, station, and visual acuity or electrical threshold. In the first series the visual acuity was taken, but in the last four series measurements of the electrical threshold were substituted for visual acuity. The collection of the urine completed the period. As the subject knew thoroughly how to cooperate and for this reason no special adjustments by the assistant were necessary, this series of eight measurements could be completed in 30 minutes without haste or difficulty and the regular half-hour schedule was quite carefully observed. The measurements followed very closely the following schedule:

Finger movements......	Maximum speed for 10 seconds, 2 records made, 1 minute.
Code test...............	Substitution of 50 letters, 2 minutes.
Pursuitmeter............	A 5-minute test, 6 minutes.
Pursuit pendulum.......	25 catches, 6 minutes.
Eye movements.........	2 series, each 5 seconds long, 2 minutes.
Eye reactions...........	15 to 20, 3 minutes.
Station	A 2-minute continuous test, 3 minutes.
Sensory threshold.......	16 to 18 determinations, 5 minutes.
Urine sample............	2 minutes.
Total time for the test period..............	30 minutes.

The first four tests were in one room, the others in an adjoining room. In all tests, except that of station, the subject was seated, and each test required a change of position, except the eye-reaction test, which followed immediately after the measurement of speed of eye movement, and with the subject in the same place. Hence he was fairly active, there being sufficient variety to maintain interest.

The results for these five 30-minute series on *Mow* may conveniently be reported together for each measurement. The complete data, i. e., the average scores for the individual periods on each day for every measurement will be given in tabular form for the first, second, and third series (water, beer, and grape-juice series in 1919). The results for the fourth series (grape-juice series of 1920) are included for the most part in the group results discussed in Chapter VI; consequently, in our comparisons in this chapter, only the final results will usually be given for this series in the text. The results for the cider-alcohol series will mostly be given in the form of charts.

It was expected that data regarding alcohol concentration would be available for all of the five series, and urine samples were regularly taken with this as the objective. Probably an insufficient amount of preservative was added to the urines and care was not taken to store the samples in a sufficiently cool place. When they were finally analyzed by the Nicloux method,[a] the results were found to be irregular, for while some of the samples showed concentrations of alcohol which later experiments lead us to expect from such an alcoholic dosage, other samples, collected 30 minutes before or after, sometimes indicated complete disappearance of the alcohol. Consequently, all of the alcohol-urine results for the first three series will be omitted from discussion and only such data compared as were obtained in the grape-juice and cider series of 1920, when the urine samples were

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Nicloux, Recherches expérimentales sur l'élimination de l'alcool dans l'organisme. Thesis, Paris, 1900, and later papers by the same author; see Miles, Journ. Pharm. and Exp.Therap., 1922, 20, p. 265, for references.

kept on ice and analyzed very shortly after collection, no preservative having been added.

In the experiments reported in this chapter, as well as in those in Chapter VI, it will be noted that *two preliminary periods* have invariably been used. This has been for the definite purpose of obtaining a more trustworthy preliminary level of performance before the dose was given. In the typewriting series of experiments, discussed in Chapters II and III, it was found that the one preliminary half-hour period is quite variable, and consequently two methods of computing the effect of alcohol were resorted to. In these experiments with dilute alcohol and those which follow we employ but one method of computing the effect of alcohol, that is, the percentage from differences, the so-called difference method. (See pp. 4 and 46). A slight amount of attention devoted to this matter will, we believe, convince the reader that this percentage effect, as computed by the method in which two preliminary periods have been averaged to get the level of performance for the day before the ingestion of the dose, is the most logical and objective method that can be used for such a comparison. The tables presenting the results for the different measurements are very uniform in construction, and aside from the original period values, which are usually averages, any of the computations can be there verified if it is desired. When the decimal is 0.5 or more, the general policy has been to raise the figure to the next unit, and if less than 0.5, to discard it.

In presenting the results, consideration will be given first to the effect of alcohol shown by the measures of motor control—static equilibrium, speed of finger movement, velocity of eye movement, and coordination with pursuit pendulum and pursuitmeter. The results for speed of eye reaction, sensory thresholds, and the transliteration of code will then be discussed in order. Finally, data for the effect of alcohol on the volume of urine and on the metabolism will be reviewed.

Static Equilibrium.

This was the first study in this group of researches in which observations were made of the effect of alcohol on static equilibrium. The station measurements were carried out with the ataxiameter which had previously been developed in the Nutrition Laboratory. A description of the apparatus and the technique has been given on page 24.

Amount of Sway.

The results of the station test for the water, beer, and grape-juice series of 1919 are given separately in table 38, which is, in fact, three small tables combined under the same heading. The series is indicated at the left, also the division between control and alcohol data and the dates of the experiments, these latter agreeing with the chronological arrangement in table 37. The control data and the alcohol data are averaged for the amount of sway for each period separately and the differences computed, as well as the differences representing the effect of the alcohol and the percentage effect.

The averages for the preliminary periods of these three series of experiments indicate that some increase of ability in this test was taking place, these in chronological order being 746, 742, 658, 637, 632, and 633 mm.

Usually, the series was arranged so that the alcohol experiments were interspersed among the control experiments, for if all of the control experiments came first and the alcohol experiments later, the improvement from practice in the test would be unevenly divided. These preliminary scores agree fairly well with what has been found on the average for adult men, as 16 men in their earliest trials with the same apparatus gave an average

TABLE 38.—*Effect of dilute alcohol on station as measured by the ataxiameter.*

Series, type, and date of experiments.	Amount of sway at successive half-hours.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Water-alcohol series, 1919:	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Control: Nov. 5	804	875	859	918	896	....	891
Nov. 8	742	896	864	849	934	....	882
Nov. 19	621	627	721	658	790	....	723
Nov. 21	665	697	643	696	674	....	671
Nov. 22	756	773	746	708	739	....	731
Averages	718	774	767	766	807	....	780
Differences	(746)		+21	+20	+61	....	+34
Alcohol: Nov. 6	771	683	908	801	813	....	841
Nov. 7	725	733	1045	903	1213	....	1054
Nov. 10	753	726	1042	968	975	....	995
Nov. 17	770	738	1037	927	1118	....	1027
Nov. 18	820	700	974	1143	1132	....	1083
Averages	768	716	1001	948	1050	....	1000
Differences	(742)		+259	+206	+308	....	+258
Effect in differences	....	....	+238	+186	+247	....	+224
Effect in per cent	(744)		+ 32.0	+ 25.0	+ 33.2	....	+ 30.1
Beer-alcohol series, 1919:							
Control: Dec. 4	648	602	521	605	631	692	612
Dec. 5	664	603	650	602	602	535	597
Dec. 10	710	660	710	683	682	643	680
Dec. 11	690	687	658	664	682	723	682
Averages	678	638	635	638	649	648	643
Differences	(658)		− 23	− 20	− 9	−10	− 16
Alcohol: Dec. 3	562	522	862	900	776	637	794
Dec. 8	654	712	980	916	778	778	863
Dec. 9	633	683	944	977	779	682	846
Dec. 13	680	653	855	1052	806	673	847
Averages	632	642	910	961	790	692	838
Differences	(637)		+273	+324	+153	+55	+201
Effect in differences	....	....	+296	+344	+162	+65	+207
Effect in per cent	(647)		+ 45.8	+ 53.2	+ 25.1	+10.0	+ 33.5
Grape juice-alcohol series, 1919:							
Control: Dec. 2	720	620	653	676	665	638	658
Dec. 16	684	658	641	605	673	688	652
Dec. 20	595	515	549	638	617	622	607
Averages	666	598	614	640	652	649	639
Differences	(632)		− 18	+ 8	+ 20	+17	+ 7
Alcohol: Dec. 1	648	698	1018	813	696	774	825
Dec. 15	703	554	858	921	761	681	805
Dec. 17	582	602	772	865	660	722	755
Dec. 18	618	661	695	866	688	748	749
Averages	638	629	836	866	701	731	784
Differences	(633)		+203	+233	+ 68	+98	+151
Effect in differences	....	....	+221	+225	+ 48	+81	+144
Effect in per cent	(632)		+ 35.0	+ 35.6	+ 7.6	+12.8	+ 22.8

of 745 mm.[a] The effect of alcohol in the water series shows an increase in swaying amounting on the average to 30.1 per cent. This is about equally prominent in all three periods following the alcohol. In the beer series the average effect is a trifle larger, 33.5 per cent, notwithstanding the fact that the experiments were continued for a longer time, that is, for four periods after the dose. The percentages for the different periods show a fairly regular course with decidedly the highest value, 53.2 per cent, in the fourth period, that is, 1 hour after the alcohol. In the grape-juice series, the direction of the alcohol effect of increase in swaying is of about the same amount for periods 3 and 4. The results in period 5 are unaccountably irregular so that the average for the four periods following the taking of alcohol is but 22.8 per cent. No well-pronounced maximum is indicated,

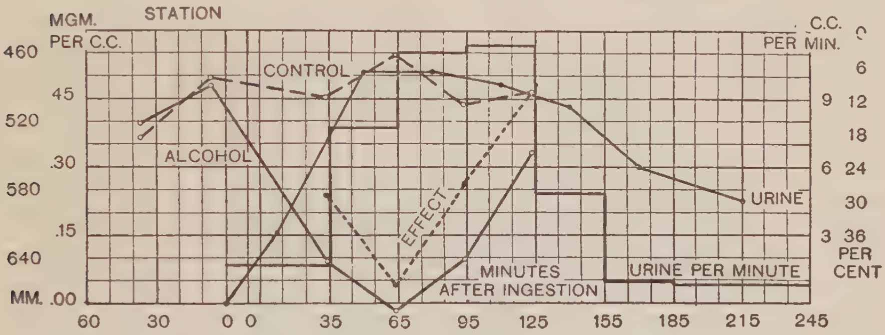

Fig. 10.—Results of Station Measurements in Cider-alcohol Series.

The extreme left-hand scale gives total millimeters of sway and applies to curves for alcohol and control. The inner left-hand scale, milligrams of alcohol per cubic centimeter, applies to the urine curve which shows the alcohol concentration in the urine at various time intervals following the complete ingestion of the dose. The inner right-hand scale applies to the excretion of urine per minute in cubic centimeters. The outer right-hand scale in per cent applies to the curve marked "effect" for the percentage alcohol effect. The number of minutes after ingestion are given on the abscissa as well as the minutes preceding ingestion by which the position of the test intervals are located. The arrangement of this chart is typical of many that are to follow in this chapter.

the increase in the hour after alcohol being about 35 per cent in both periods. The fourth series, grape juice and alcohol in 1920, which is not included in table 38, gave effects for the four periods following alcohol of −4.5, +23.3, +11.9, and −2.4, with an average of +7.1 per cent. (See table 62, p. 239.)

The effect in the cider-alcohol series, as well as the average data for these control and alcohol experiments, are shown in the chart in figure 10. The extreme left-hand scale gives total millimeters of sway obtained by adding the score for all of the four movement adders. This scale applies to the curves marked "control" and "alcohol." The inner left-hand scale, designated "mgm. per c. c." applies to the curve marked "urine," which indicates concentration of alcohol in the urine at various times following the ingestion of the alcohol. The time relations of the control and alcohol measurements, of the urine curve, and of the curve for the effect of alcohol are shown on the abscissa as minutes prior to and after ingestion. The extreme right-hand scale applies to the curve marked "effect," which gives the percentage effect of the alcohol.

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[a] Miles, Journ. Industr. Hygiene, 1922, 3, p. 328.

The chart shows very readily the marked contrast between the results following the taking of the alcohol solution as compared to those following the ingestion of the control solution. While the preliminary values for both series are closely the same, those following the alcohol indicate an immediate change, while those following the control dose remain at essentially the same level. After the alcohol the ability to stand motionless drops suddenly and prominently, but recovers to a large extent in periods 5 and 6. The alcohol effect for the various periods in order is 29.1, 44.9, 27.0, and 10.8, with an average of 28.0. The maximum effect in this instance appears to occur at about the time the alcohol reaches its maximum concentration in the urine, but the effect seemingly decreases more rapidly than the alcohol concentration falls in the urine.

This comparison of the time relations of the alcohol effect and of the concentration in the urine in this and succeeding charts is worthy of note. So far as the writer is acquainted with alcohol literature, such relationships between the influence of alcohol and its concentration in the body fluids have never before been objectively obtained. The curves have been drawn in such a way that when the alcohol effect is in the direction of a decrease in efficiency or a poorer grade of performance, as judged from the normal, the curve moves downward. Thus it tends to parallel the alcohol performance, which is also charted in such a way that a downward direction of the curve indicates a poorer score. Accordingly, the curve for the alcohol effect frequently takes much the same shape as in figure 10. In these five series of experiments, since the periods were 30 minutes long, the plotted points on each curve are 30 minutes apart. The urine values are plotted midway of the 30-minute intervals. A still more accurate comparison as to time relations between the two curves will be possible in the experiments with *Mow* in which 15-minute periods were used.

The volume of each urine sample was always recorded and a urine per minute curve has been plotted in blocks in each chart for a more complete presentation of the urine data. Its general form corresponds roughly with that of the alcohol concentration in the urine, but even in this case it is observed that the highest point in one curve does not coincide with the highest value in the other. The two curves will not superimpose. In fact, the alcohol concentration in the urine was found by Widmark[a] and later by Miles[b] to be independent of the diuresis or the amount of urine passed per minute.

AREA OF SWAY.

In most of these station tests, graphic records were made at the same time that the ataxiameter score was taken. The graphic tracing has an advantage in that it shows the general scatter or area of the swaying. In the common observation of an individual, who is ill or intoxicated, it is the area of sway that claims our attention and likewise in the usual administering of the Romberg test. A large amount of sway is associated usually with a large area of sway and vice versa.

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[a] Widmark, Skand. Arch. f. Physiol., 1916, **33**, p. 85.

[b] Miles, Journ. Pharm. and Exp. Therapeutics, 1920, **20**, p. 265.

Typical graphic records for this subject and for these series of experiments are illustrated in figure 11. The upper tracings were obtained in the control experiment of December 11, 1919, which was the last control day in the beer-alcohol series; the lower tracings were obtained in the complementary alcohol experiment on December 13, 1919. Below each tracing the period number is given, together with the scores for amount of sway and for the computed area. The normal tracings are usually longer than they are broad and tend to be somewhat elliptical in form. In each case the lowest portion of the tracing would represent the extreme forward sway. As a rule, the subject, in swaying forward moved somewhat to the right, and in swaying backward to the left. Between periods 2 and 3 and, of course, nearly 40 minutes before tracing 3 was taken on the control day, the liter of control solution was ingested. The areas of tracings in periods 4, 5, and 6 are somewhat larger (see table 39) than the average for the two preliminary periods, although the millimeter scores for the *amount* of sway in periods 4 and 5 are not larger than similar scores in periods 1 and 2. In the alcohol experiment on December 13, as indicated in the lower horizontal line of tracings, a liter of liquid containing 2.75 per cent of alcohol (27.5 grams) was taken between periods 2 and 3 and about 40 minutes before tracing 3 was made. It is very obvious that there is a difference between tracings 3, 4, and 5 and those for the preliminary periods on this same day or for the comparison periods above. From these particular tracings it

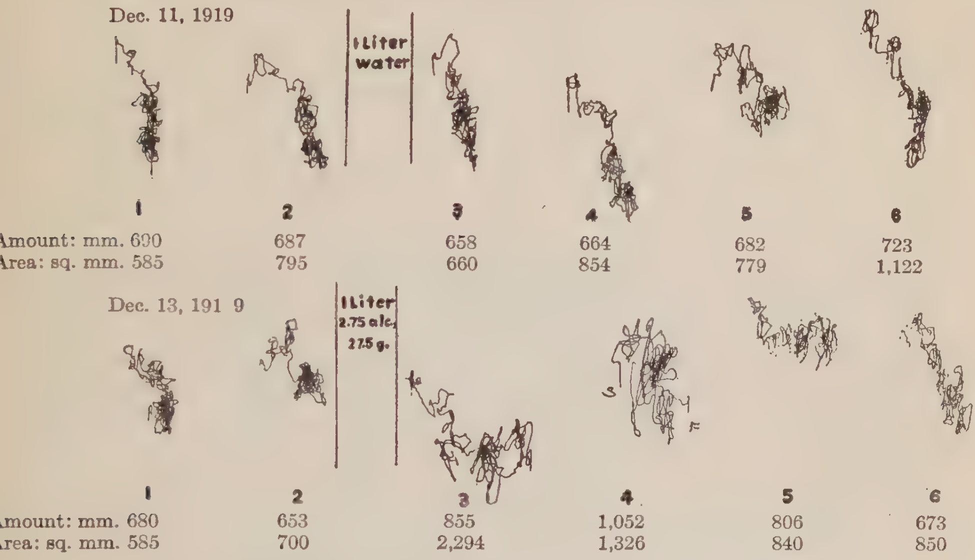

FIG. 11.—Typical Series of Graphic Records from Station Tests.

Upper series: Control day (December 11), with 1 liter non-alcoholic beer and water taken between periods 2 and 3. Lower series: Alcohol day (December 13), with 27.5 grams alcohol in 1-liter solution (2.75 per cent alcohol by weight) taken between periods 2 and 3. The change in area of sway after alcohol is obvious.

appears that the lateral component of movement is especially accentuated. It is interesting to note the difference between the scores for the amount of sway and those for the area of sway. On December 13 (see lower portion of figure 11) the area is considerably greater in period 3 than in 4, but the amount of sway is larger in period 4.

The areas in square millimeters for the graphic tracings have been measured by finding the smallest rectangle that would completely inclose the tracing. This rectangle has been placed on the graphic record without regard to the absolute anterior-posterior and lateral axes, that is, no atten-

TABLE 39.—*Effect of dilute alcohol on station as measured by the graphic method.*

Series, type, and date of experiments.	Area of sway at successive half-hours.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Water-alcohol series, 1919:	*sq.mm.*	*sq.mm.*	*sq. mm.*	*sq. mm.*	*sq. mm.*	*sq. mm.*	*sq. mm.*
Control: Nov. 19	1650	1080	1160	1224	1794	....	1393
Nov. 21	1003	1380	704	1020	1428	....	1051
Nov. 22	1224	1155	1060	1540	1144	....	1248
Averages	**1292**	**1205**	**975**	**1261**	**1455**	....	**1230**
Differences	(1249)		−274	+ 12	+206	....	− 19
Alcohol: Nov. 17	1520	600	1728	989	1568	....	1428
Nov. 18	1088	855	1144	1768	1643	....	1518
Averages	**1304**	**728**	**1436**	**1379**	**1606**	....	**1474**
Differences	(1016)		+420	+363	+590	....	+458
Effect in differences	....	....	+694	+351	+384	....	+476
Effect in per cent	(1133)		+ 61	+ 31	+ 34	....	+ 42
Beer-alcohol series, 1919:							
Control: Dec. 4	780	612	570	627	731	1008	734
Dec. 5	918	595	564	585	524	784	614
Dec. 10	825	720	1121	840	800	924	921
Dec. 11	585	795	660	854	779	1122	854
Averages	**777**	**681**	**729**	**727**	**709**	**960**	**781**
Differences	(729)		± 0	− 2	− 20	+231	+ 52
Alcohol: Dec. 3	646	777	1120	1333	1056	570	1020
Dec. 8	901	645	1239	1512	1152	741	1161
Dec. 9	456	1265	1380	2684	1560	924	1637
Dec. 13	585	700	2294	1326	840	850	1328
Averages	**647**	**847**	**1508**	**1714**	**1152**	**771**	**1286**
Differences	(747)		+761	+967	+405	+ 24	+539
Effect in differences	....	....	+761	+969	+425	−207	+487
Effect in per cent	(738)		+103	+131	+ 58	− 28	+ 66
Grape-juice-alcohol series, 1919:							
Control: Dec. 2	1200	720	936	896	795	900	882
Dec. 16	735	848	440	665	770	954	707
Dec. 20	324	385	444	738	714	330	557
Averages	**753**	**651**	**607**	**766**	**760**	**728**	**715**
Differences	(702)		− 95	+ 64	+ 58	+ 28	+ 14
Alcohol: Dec. 1	784	688	1914	828	546	1170	1115
Dec. 15	608	675	1363	1620	1026	816	1206
Dec. 17	616	605	840	1134	819	660	863
Dec. 18	410	672	855	1450	1250	1540	1274
Averages	**605**	**660**	**1243**	**1258**	**910**	**1047**	**1115**
Differences	(633)		+610	+625	+277	+414	+482
Effect in differences	....	....	+705	+561	+219	+386	+468
Effect in per cent	(668)		+106	+ 84	+ 33	+ 58	+ 70

tion has been paid to the real axes of the smoked paper, and the tracing has been given every advantage for the reduction of its square millimeters of area. Measurements made in this way provide us with the data given in table 39. Graphic records were not made on November 5, 6, 7, 8, and 10 of the water-alcohol series of 1919, so that the results given in the table are for only two alcohol and three control days of this series. It will be seen from the preliminary values that the area fluctuated even under what appears to be normal conditions; accordingly a close agreement between the results for the different series of alcohol experiments can hardly be expected. The water-alcohol series shows increases in area after alcohol of 61, 31, and 34 per cent for periods 3, 4, and 5, with an average for the interval following the alcohol of 42 per cent. The increases in the beer-alcohol series are in general larger, with a maximum of 131 per cent in period 4, but a minus value in period 6. The average for the 2 hours is an increase of 66 per cent in the area of sway. The grape-juice series of 1919 gives the highest increase in area of sway in period 3 with 106 per cent, with percentages of +84, +33, and +58 for the succeeding periods, and an average of +70 per cent for the four periods after alcohol. The grape-juice-alcohol series of 1920 gives an increase of 45 per cent in period 4 as a maximum. (See table 63, p. 242.) In the other periods, the changes are rather slight with −38 per cent in period 6. The cider-alcohol series shows +28 per cent in period 4, but all of the other periods are minus.

We may conclude from these measurements of the *area* of sway taken from graphic tracings while the subject is endeavoring to stand still, that a solution containing 2.75 per cent of alcohol increases the scatter or range of such swaying as a general thing, but that measurements made in this way are more rough and less uniform from period to period than when the *amount* of the sway is recorded on the ataxiameter. The station test is a sensitive indicator of the effect of alcohol and shows roughly a decrease in efficiency of about 35 per cent as a maximum 1 hour after the ingestion of 27.5 grams of alcohol in a liter of solution.

FINGER MOVEMENTS.

The technique of the measurement of the finger movements in this study with a trained subject and in the study reported in the following chapter differed from the method used with the typists in that the movements were recorded on a kymograph instead of photographically. The method has already been described. (See p. 16.)

SPEED OF FINGER MOVEMENTS.

The average performance for this subject varied closely from 75 to 77 finger oscillations in 10 seconds. A comparison with the scores for other subjects in Chapter II as well as in Chapter VI indicates that this is a fairly rapid rate. There is no observable continuous improvement from practice shown in table 40. In general, the speed of the finger movement decreases slightly after the control dose, but the decrease after alcohol was still more marked. The percentage effects of alcohol are practically always minus in direction. In the water-alcohol series, they are −1.7, −4.1, and −2.6 per cent, with an average of −2.8 per cent; in the beer-alcohol series they are −0.4, −2.6, −3.8, and −3.2 per cent, with an average of −2.5 per cent. The effect was a little less with the grape-juice-alcohol series of 1919, being +1.0, −1.7, −1.9, and −2.3 per cent for periods 3 to 6, respectively, averaging −1.2 per cent. The grape-juice-alcohol series of 1920 (the results of which are published in detail in Chapter VI) gave +0.1, −1.3, −4.8, ±0, and average −1.5 per cent. (See table 64, p. 244.) The chart for

TABLE 40.—*Effect of dilute alcohol on speed of voluntary finger movements.*

Series, type, and date of experiments.	No. in 10 seconds at successive half-hours.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Water-alcohol series, 1919:							
Control: Nov. 5	75.9	74.8	73.2	73.4	73.6	....	73.4
Nov. 8	75.5	74.5	73.7	74.6	74.3	....	74.2
Nov. 19	77.4	75.7	75.5	74.9	76.2	....	75.5
Nov. 21	76.7	74.9	74.1	74.7	73.0	....	73.9
Nov. 22	76.5	75.1	76.4	75.4	73.8	....	75.2
Averages	76.4	75.0	74.6	74.6	74.2	....	74.5
Differences	(75.7)		−1.1	−1.1	−1.5	....	−1.2
Alcohol: Nov. 6	77.1	75.0	74.8	72.8	72.4	....	73.3
Nov. 7	78.0	77.3	75.6	73.1	73.7	....	74.1
Nov. 10	77.5	75.5	73.3	71.6	73.8	....	72.9
Nov. 17	78.7	77.6	74.7	72.4	73.7	....	73.6
Nov. 18	78.4	76.6	75.3	74.6	74.6	....	74.8
Averages	77.9	76.4	74.7	72.9	73.6	....	73.7
Differences	(77.1)		−2.4	−4.2	−3.5	....	−3.4
Effect in differences	....		−1.3	−3.1	−2.0	....	−2.1
Effect in per cent	(76.4)		−1.7	−4.1	−2.6	....	−2.8
Beer-alcohol series, 1919:							
Control: Dec. 4	75.8	76.9	76.5	75.4	75.4	75.4	75.7
Dec. 5	77.9	77.6	76.1	76.1	76.9	76.0	76.3
Dec. 10	78.6	76.7	75.1	76.8	75.6	76.6	76.0
Dec. 11	78.6	75.5	74.8	77.0	76.9	75.5	76.1
Averages	77.7	76.7	75.6	76.3	76.2	75.9	76.0
Differences	(77.2)		−1.6	−0.9	−1.0	−1.3	−1.2
Alcohol: Dec. 3	75.5	75.2	74.3	73.1	72.8	73.2	73.4
Dec. 8	79.3	78.0	75.6	74.7	73.7	72.7	74.2
Dec. 9	79.1	78.1	76.6	75.4	74.3	74.7	75.3
Dec. 13	77.1	77.9	76.0	75.4	73.7	74.3	74.9
Averages	77.7	77.3	75.6	74.6	73.6	73.7	74.4
Differences	(77.5)		−1.9	−2.9	−3.9	−3.8	−3.1
Effect in differences	....		−0.3	−2.0	−2.9	−2.5	−1.9
Effect in per cent	(77.3)		−0.4	−2.6	−3.8	−3.2	−2.5
Grape-juice-alcohol series, 1919:							
Control: Dec. 2	75.9	75.7	73.3	74.3	73.9	75.2	74.2
Dec. 16	78.9	76.2	75.3	76.8	76.6	76.1	76.2
Dec. 20	78.7	78.4	77.0	77.0	76.5	76.6	76.8
Averages	77.8	76.8	75.2	76.0	75.7	76.0	75.7
Differences	(77.3)		−2.1	−1.3	−1.6	−1.3	−1.6
Alcohol: Dec. 1	77.2	76.9	74.8	73.7	72.9	72.5	73.5
Dec. 15	77.0	76.6	76.0	73.2	74.0	73.3	74.1
Dec. 17	78.5	77.2	76.9	76.2	75.1	76.6	76.2
Dec. 18	77.6	76.8	76.1	75.5	74.4	74.0	75.0
Averages	77.6	76.9	75.9	74.6	74.1	74.1	74.7
Differences	(77.2)		−1.3	−2.6	−3.1	−3.1	−2.5
Effect in differences	....		+0.8	−1.3	−1.5	−1.8	−1.0
Effect in per cent	(77.2)		+1.0	−1.7	−1.9	−2.3	−1.2

the finger-movement data of the cider-alcohol series is given in figure 12. The average performances for control and alcohol days follow each other very closely until the second period after alcohol, when the speed begins to decline; this decline shows clearly in periods 5 and 6. The effect of the alcohol is most prominent in period 5, being a decrease in speed of finger movement of 2.4 per cent. The urine curve and the urine per minute curve are likewise given as in the previous chart. The maximal effect of the alcohol follows the maximal concentration in the urine. Only in the water-alcohol series was the maximal effect on the finger movement as early as period 4; in the other series it tends to appear in period 5, and in one case (the grape-juice series of 1919) it is in period 6.

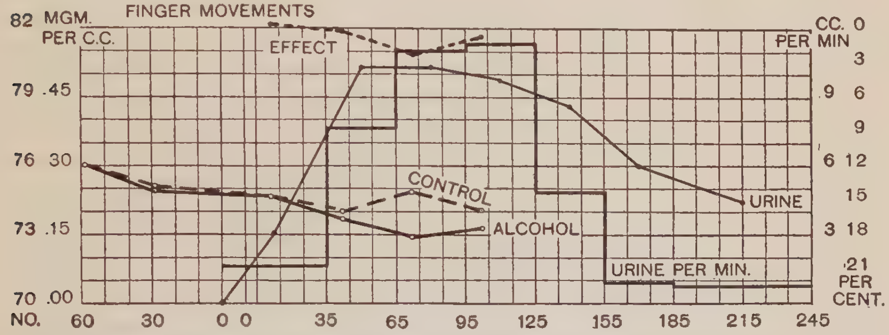

Fig. 12.—Alcohol Effect on Finger Movement Compared with Concentration of Alcohol in Urine at Intervals After Ingestion. (Cider-alcohol Series, 1920, Subject *Mow.*)

While the effect of the alcohol is not large, usually less than 4 per cent, thus agreeing with the results found in the alcohol typewriting series, it is nevertheless quite clearly in the direction of a reduction in the speed of finger movement following the dilute alcohol.

Amplitude of Finger Movements.

In none of the publications from the Nutrition Laboratory giving the results of studies in which the finger movements have been used as a measurement of neuro-muscular control have we given any consideration to the amplitude of these movements, the speed being the only factor computed and reported. It seemed logical to limit the presentation of the results to the speed because of the wide variation in amplitude adopted by different subjects. In July 1922, when a large number of the records were spread out for inspection of the time records on them, we were strongly impressed with the variation in the *amplitude* and in the *character* of the finger movements following alcohol in the tests with *Mow.* In a preliminary sorting of the records, with no reference whatever to dates or to groups of records, it appeared that the tracings made by this man after alcohol could usually be recognized without difficulty.

The differences may be seen in figure 13, which reproduces part of six tracings taken on one alcohol day (November 7, 1919, periods 3, 4, and 5). Only sections of the tracings are reproduced, but these are typical. *A* and *B* are from period 3 and, as they were performed about 5 minutes after taking alcohol, they may be considered about normal. *C* and *D* (period 4) and

E and *F* (period 5) are clearly of a different character. The average amplitude of these latter appears somewhat reduced, but the particular feature to be noted is the variance of the successive finger movements in their height of flexion and extension.[a] In view of these changes in character,

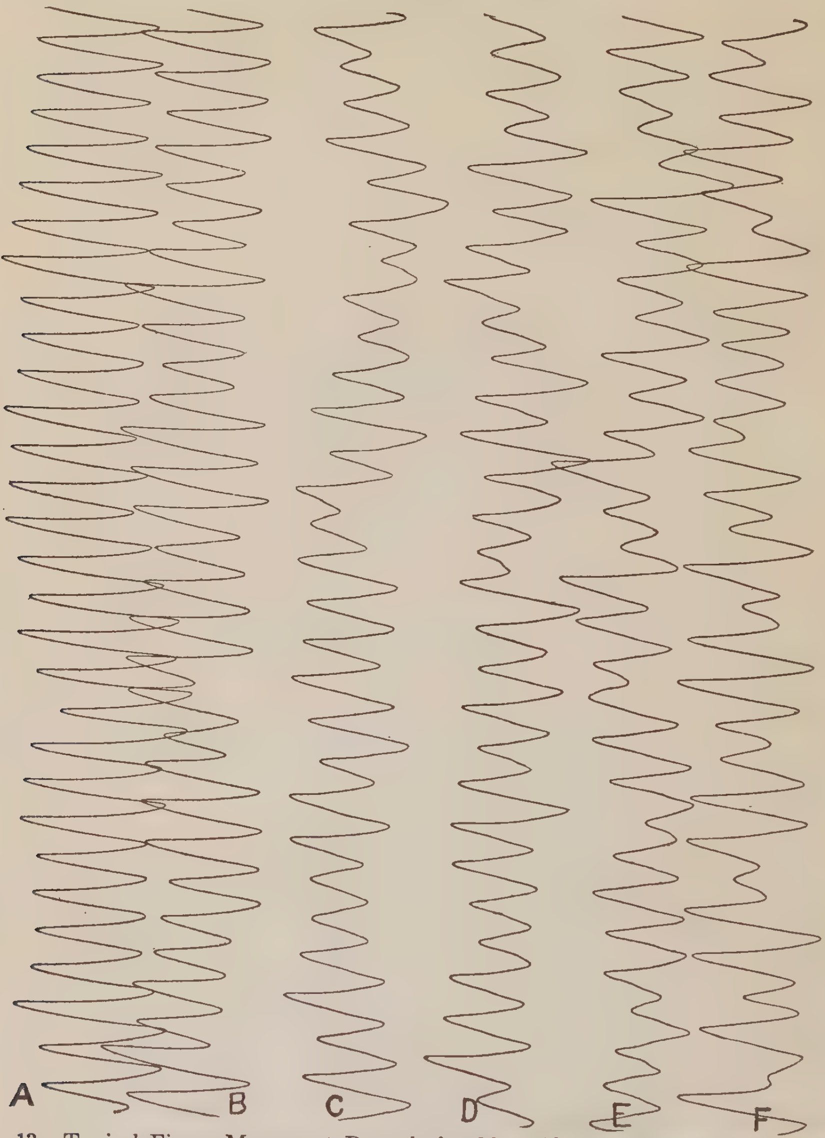

FIG. 13.—Typical Finger Movement Records for *Mow*, Showing Characteristic Change in Amplitude and in Variability of Amplitude After Alcohol.

Part of record for November 7, 1919. Tracings *A* and *B* were made in period 3 about 5 minutes after the ingestion of alcohol, *C* and *D* were made in period 4, about 35 minutes after ingestion, while *E* and *F* were made 30 minutes later.

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[a] In the figure a movement to the right is always flexion of the finger. The record was made proceeding downward.

TABLE 41.—*Effect of dilute alcohol on amplitude of voluntary finger movements.*

Series, type, and date of experiments.	Average amplitude at successive half-hours.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Water-alcohol series, 1919:	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Control: Nov. 5	16.1	14.9	13.4	12.9	13.3	....	13.2
Nov. 8	22.8	22.3	21.5	19.0	15.4	....	18.6
Nov. 19	28.4	36.6	26.3	22.9	19.8	....	23.0
Nov. 21	28.1	26.8	25.6	16.6	15.0	....	19.1
Nov. 22	27.3	24.5	22.3	19.2	19.7	....	20.4
Averages	24.5	25.0	21.8	18.1	16.6	....	18.8
Differences	(24.8)		− 3.0	− 6.7	− 8.2	....	− 6.0
Alcohol: Nov. 6	24.7	17.8	17.1	15.5	14.6	....	15.7
Nov. 7	23.2	22.2	21.1	13.8	13.5	....	16.1
Nov. 10	18.9	19.7	20.1	13.9	13.8	....	15.9
Nov. 17	27.2	27.7	18.8	19.4	15.8	....	18.0
Nov. 18	29.3	29.3	23.4	17.1	17.6	....	19.4
Averages	24.7	23.3	20.1	15.9	15.1	....	17.0
Differences	(24.0)		− 3.9	− 8.1	− 8.9	....	− 7.0
Effect in differences	......	......	− 0.9	− 1.4	− 0.7	....	− 1.0
Effect in per cent	(24.4)		− 3.7	− 5.7	− 2.9	....	− 4.1
Beer-alcohol series, 1919:							
Control: Dec. 4	16.7	11.7	11.7	10.5	13.4	16.8	13.1
Dec. 5	13.6	14.8	14.9	13.4	14.1	12.6	13.8
Dec. 10	16.4	18.5	18.0	12.3	13.2	13.7	14.3
Dec. 11	14.0	14.2	14.6	13.3	13.4	12.8	13.5
Averages	15.2	14.8	14.8	12.4	13.5	14.0	13.7
Differences	(15.0)		− 0.2	− 2.6	− 1.5	− 1.0	− 1.3
Alcohol: Dec. 3	16.8	16.1	12.5	12.2	11.3	10.4	11.6
Dec. 8	17.1	15.8	13.5	9.6	8.4	11.4	10.7
Dec. 9	17.5	17.7	14.8	10.1	9.9	9.5	11.1
Dec. 13	14.4	15.9	12.8	9.9	9.5	9.6	10.5
Averages	16.5	16.4	13.4	10.5	9.8	10.2	11.0
Differences	(16.5)		− 3.1	− 6.0	− 6.7	− 6.3	− 5.5
Effect in differences	......	......	− 2.9	− 3.4	− 5.2	− 5.3	− 4.2
Effect in per cent	(15.8)		−18.4	−21.5	−32.9	−33.5	−26.6
Grape-juice-alcohol series, 1919:							
Control: Dec. 2	16.3	15.5	15.6	15.1	13.5	13.7	14.5
Dec. 16	15.4	17.5	15.9	14.6	17.1	17.2	16.2
Dec. 20	20.9	20.4	19.6	18.4	17.0	15.9	17.7
Averages	17.5	17.8	17.0	16.0	15.9	15.6	16.1
Differences	(17.7)		− 0.7	− 1.7	− 1.8	− 2.1	− 1.6
Alcohol: Dec. 1	19.3	18.5	14.5	12.0	13.3	12.0	13.0
Dec. 15	14.0	13.8	11.5	11.0	9.8	10.0	10.6
Dec. 17	18.0	18.3	14.8	10.8	12.5	16.8	13.7
Dec. 18	18.0	15.9	15.8	13.2	12.4	12.8	13.6
Averages	17.3	16.6	14.2	11.8	12.0	12.9	12.7
Differences	(17.0)		− 2.8	− 5.2	− 5.0	− 4.1	− 4.3
Effect in differences	......	......	− 2.1	− 3.5	− 3.2	− 2.0	− 2.7
Effect in per cent	(17.4)		−12.1	−20.1	−18.4	−11.5	−15.5
Grape-juice-alcohol series, 1920:							
Control: Dec. 8	25.5	29.4	25.3	24.4	24.7	24.6	24.8
Dec. 11	24.5	23.0	21.4	22.1	20.5	16.7	20.2
Averages	25.0	26.2	23.4	23.3	22.6	20.7	22.5
Differences	(25.6)		− 2.2	− 2.3	− 3.0	− 4.9	− 3.1
Alcohol: Dec. 9	22.9	19.5	20.6	19.9	16.9	16.6	18.5
Dec. 10	21.6	22.9	20.1	18.5	15.4	17.8	18.0
Averages	22.3	21.2	20.4	19.2	16.2	17.2	18.3
Differences	(21.8)		− 1.4	− 2.6	− 5.6	− 4.6	− 3.6
Effect in differences	......	......	+ 0.8	− 0.3	− 2.6	+ 0.3	− 0.5
Effect in per cent	(23.7)		+ 3.4	− 1.3	−11.0	+ 1.3	− 1.9

TABLE 41.—*Effect of dilute alcohol on amplitude of voluntary finger movements*—Continued.

Series, type, and date of experiments.	Average amplitude at successive half-hours.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Cider-alcohol series, 1920:	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Control: Dec. 15	24.3	25.6	22.6	25.0	24.7	23.7	24.0
Dec. 18	29.6	21.5	20.1	22.2	22.0	19.0	20.8
Dec. 22	20.2	20.7	20.1	21.8	22.4	21.3	21.4
Averages	**24.7**	**22.6**	**20.9**	**23.0**	**23.0**	**21.3**	**22.1**
Differences	(23.7)		**− 2.8**	**− 0.7**	**− 0.7**	**− 2.4**	**− 1.7**
Alcohol: Dec. 13	24.7	21.2	17.3	14.9	16.3	18.8	16.8
Dec. 16	25.0	26.0	23.3	16.3	15.3	16.0	17.7
Dec. 17	22.0	24.5	19.3	15.8	13.8	18.3	16.8
Dec. 20	23.8	21.8	16.3	12.3	11.0	10.3	12.5
Averages	**23.9**	**23.4**	**19.1**	**14.8**	**14.1**	**15.9**	**16.0**
Differences	(23.7)		**− 4.6**	**− 8.9**	**− 9.6**	**− 7.8**	**− 7.7**
Effect in differences	......	......	− 1.8	− 8.2	− 8.9	− 5.4	− 6.1
Effect in per cent	(23.7)		− 7.6	−34.6	−37.5	−22.8	−25.6

measurements of *Mow's* records are necessary, since he is thoroughly practiced in this measure and had absolutely no knowledge that his method of performing the finger movement was any different after the alcohol dose from that after the control dose. If an alcohol effect of this nature was found really to exist, it could not be ascribed to subjective bias, but must arise from the efforts to keep up the speed of the movement after the alcohol had been ingested.

To measure the height of all of the individual finger movements of all the tracings which had been taken on *Mow* was indeed a very large task and seemed unnecessary. It was arbitrarily decided to measure 25 oscillations in each record, the height of extension and flexion being measured separately, thus giving 50 measurements in all for each tracing. These 50 measurements were averaged to provide one value to represent the score for the amplitude of that record. Two records of the finger movements were taken in each period in these five experimental series on *Mow*, and 25 consecutive finger oscillations were measured on both of these records. The position in the record chosen for the measurement was constant. When making the record, the tracing always began at the seam of the paper; therefore it was convenient to begin the measurement of amplitudes where the paper had been cut and at the end farthest from the beginning of the test. It must be clearly understood that we did not pick out the jerky, irregular spots in the tracings and measure these, although such spots often exist, as do illegible spots in the typewriting records. We arbitrarily selected a certain position for measurement of all records, and the result from this fairly large sample was taken as typical for the record. The individual measurements were to the nearest half-millimeter.

The results of these measurements of the amplitude are given in table 41 and include all five series. They indicate from 10 to 30 mm. as the

TABLE 42.—*Effect of dilute alcohol on variability in amplitude of finger movements.*

Series, type, and date of experiments.	Coefficient of variability at successive half-hours.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Water-alcohol series, 1919:	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*
Control: Nov. 5.......	13.3	18.1	21.7	15.4	16.9	....	18.0
Nov. 8.......	14.5	14.7	14.1	13.4	16.5	....	14.7
Nov. 19.......	12.1	10.7	10.6	15.3	17.1	....	14.3
Nov. 21.......	12.2	11.6	12.7	17.6	18.5	....	16.3
Nov. 22.......	11.2	11.4	14.1	16.6	15.9	....	15.5
Averages............	**12.7**	**13.3**	**14.6**	**15.7**	**17.0**	....	**15.8**
Differences..........	(13.0)		+ 1.6	+ 2.7	+ 4.0	....	+2.8
Alcohol: Nov. 6.......	13.3	16.3	14.3	19.2	20.4	....	18.0
Nov. 7.......	9.1	12.5	14.5	23.1	31.9	....	23.2
Nov. 10.......	10.7	14.9	15.9	19.8	35.7	....	23.8
Nov. 17.......	7.6	10.8	16.1	18.7	22.9	....	19.2
Nov. 18.......	8.8	11.6	14.0	19.9	18.4	....	17.4
Averages............	**9.9**	**13.2**	**15.0**	**20.1**	**25.9**	....	**20.3**
Differences..........	(11.6)		+ 3.4	+ 8.5	+14.3	....	+ 8.7
Effect in differences....	......	......	+ 1.8	+ 5.8	+10.3	....	+ 6.0
Effect in per cent.......	(12.3)		+14.6	+47.2	+83.8	....	+48.5
Beer-alcohol series, 1919:							
Control: Dec. 4.......	10.4	14.3	15.4	15.9	12.7	12.6	14.2
Dec. 5.......	11.0	15.2	13.5	14.9	18.7	13.6	15.2
Dec. 10.......	14.3	12.1	11.7	14.3	15.0	18.2	14.8
Dec. 11.......	16.3	15.7	12.6	14.5	17.5	14.9	14.9
Averages............	**13.0**	**14.3**	**13.3**	**14.9**	**16.0**	**14.8**	**14.8**
Differences..........	(13.7)		− 0.4	+ 1.2	+ 2.3	+ 1.1	+ 1.1
Alcohol: Dec. 3.......	11.8	13.8	22.9	17.3	21.4	18.9	20.1
Dec. 8.......	13.2	13.3	13.4	25.2	26.3	20.9	21.5
Dec. 9.......	13.7	10.8	14.6	24.0	18.8	25.4	20.7
Dec. 13.......	12.5	13.3	20.5	21.8	21.8	23.6	21.9
Averages............	**12.8**	**12.8**	**17.9**	**22.1**	**22.1**	**22.2**	**21.1**
Differences..........	(12.8)		+ 5.1	+ 9.3	+ 9.3	+ 9.4	+ 8.3
Effect in differences....	......	......	+ 5.5	+ 8.1	+ 7.0	+ 8.3	+ 7.2
Effect in per cent.......	(13.3)		+41.3	+60.9	+52.6	+62.4	+54.3
Grape-juice-alcohol series, 1919:							
Control: Dec. 2.......	12.6	12.0	12.5	12.9	13.8	14.3	13.4
Dec. 16.......	13.7	11.5	13.7	15.9	12.3	12.7	13.7
Dec. 20.......	11.1	13.8	15.6	14.4	14.8	18.3	15.8
Averages............	**12.5**	**12.4**	**13.9**	**14.4**	**13.6**	**15.1**	**14.3**
Differences..........	(12.5)		+ 1.4	+ 1.9	+ 1.1	+ 2.6	+ 1.8
Alcohol: Dec. 1.......	12.2	8.6	14.1	17.9	19.0	17.2	17.1
Dec. 15.......	15.4	14.6	17.9	14.6	21.2	28.0	20.4
Dec. 17.......	11.6	12.9	16.6	19.6	18.4	12.9	16.9
Dec. 18.......	13.6	16.4	18.1	22.9	27.2	22.4	22.7
Averages............	**13.2**	**13.1**	**16.7**	**18.8**	**21.5**	**20.1**	**19.3**
Differences..........	(13.2)		+ 3.5	+ 5.6	+ 8.3	+ 6.9	+ 6.1
Effect in differences....	......	......	+ 2.1	+ 3.7	+ 7.2	+ 4.3	+ 4.3
Effect in per cent.......	(12.9)		+16.3	+28.7	+55.8	+33.3	+33.5
Grape-juice-alcohol series, 1920:							
Control: Dec. 8.......	12.5	9.7	14.1	15.6	14.3	13.5	14.4
Dec. 11.......	12.0	13.7	14.7	13.2	15.7	17.2	15.2
Averages............	**12.3**	**11.7**	**14.4**	**14.4**	**15.0**	**15.4**	**14.8**
Differences..........	(12.0)		+ 2.4	+ 2.4	+ 3.0	+ 3.4	+ 2.8
Alcohol: Dec. 9.......	10.5	9.6	14.0	17.3	24.4	21.2	19.2
Dec. 10.......	11.1	13.8	14.3	22.7	39.7	24.1	25.2
Averages............	**10.8**	**11.7**	**14.2**	**20.0**	**32.1**	**22.7**	**22.3**
Differences..........	(11.3)		+ 2.9	+ 8.7	+20.8	+11.4	+11.0
Effect in differences....	......	......	+ 0.5	+ 6.3	+17.8	+ 8.0	+ 8.2
Effect in per cent.......	(11.7)		+ 4.3	+53.8	+152.1	+68.4	+69.7

TABLE 42.—*Effect of dilute alcohol on variability in amplitude of finger movements*—Continued.

Series, type, and date of experiments.	Coefficient of variability at successive half-hours.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Cider-alcohol series, 1920:	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*
Control: Dec. 15	11.1	13.3	11.9	13.6	12.4	11.4	12.3
Dec. 18	9.9	14.2	14.0	14.5	12.7	19.5	15.2
Dec. 22	12.7	14.3	15.1	14.6	12.3	15.5	14.4
Averages	**11.2**	**13.9**	**13.7**	**14.2**	**12.5**	**15.5**	**14.0**
Differences	(12.6)		**+ 1.1**	**+ 1.6**	**− 0.1**	**+ 2.9**	**+ 1.4**
Alcohol: Dec. 13	12.9	13.4	14.8	20.2	16.5	15.7	16.8
Dec. 16	10.2	13.3	13.6	16.7	20.1	22.9	18.3
Dec. 17	14.7	9.3	14.9	16.3	22.6	20.5	18.6
Dec. 20	11.6	11.7	16.0	20.9	29.6	30.3	24.2
Averages	**12.4**	**11.9**	**14.8**	**18.5**	**22.2**	**22.4**	**19.5**
Differences	(12.2)		+ 2.6	+ 6.3	+10.0	+10.2	+ 7.3
Effect in differences	......	......	+ 1.5	+ 4.7	+10.1	+ 7.3	+ 5.9
Effect in per cent	(12.4)		+12.1	+37.9	+81.5	+58.9	+47.6

range of normal amplitude of movement. The movements are regularly smaller after alcohol, and thus the effect is nearly always in the minus direction, the grape-juice-alcohol series of 1920 being the only one with plus values. (See periods 3 and 6.) The effect is usually at its maximum in period 4 or 5, and in some cases the change is larger than 30 per cent. The average results following the alcohol for each of the five series, as given in the table, are −4.1, −26.6, −15.5, −1.9, and −25.6 per cent. The effect was least in the fourth series (the grape-juice-alcohol series of 1920), where, as noted, there were two periods with small plus percentages.

For each tracing the mean variation was found for the group of 50 individual measurements, and this was divided by the average amplitude for the group to obtain the coefficient of variability. The coefficients are given in table 42. The period coefficients represent the average of the coefficients obtained for the two tracings made in each period. The coefficients of variability, as shown in the preliminary values for all the series for both control and alcohol days, seem to us remarkably constant at 12 to 13 per cent. A most casual inspection of the table reveals that the variability values are definitely larger after alcohol. The averages in the fourth and fifth periods after the alcohol ingestion quite commonly show a percentage variability of 20 to 22 per cent. The effect of the alcohol in all five series is marked and quite uniform, the maximal effect usually occurring in the fifth period. All five series are more nearly alike in the size of the alcohol effect and in the regularity of increase and decrease during the four periods than was found to be the case with the speed of finger movement or with the amplitude. The maximal effects for the five series in order are approximately 84, 62, 56, 152, and 82 per cent, respectively, for the increase in variability. The highest effect was in the fourth series (the grape-juice-alcohol series of 1920), in which the effect on the speed of finger movement was not particularly marked.

We are convinced that the results are not to be accounted for by any subjective bias or impression on the part of the subject who served. As an evidence of the effect of alcohol, they may represent something of an individual peculiarity on the part of subject *Mow*, but we think it more probable that they represent the situation which exists when the effect of alcohol is measured on a man who is thoroughly practiced in the finger-movement test and who throughout control and alcohol sessions seriously endeavors to keep his oscillation rate up to maximum, with no thought whatever about the amplitude of the movement. As will be seen later (see page 245), this conclusion was not substantiated in studies made with a group of young men.

Conclusions on Effect of Alcohol Upon Finger Movements.

Three features of the finger-movement data on a trained subject have been measured—speed, amplitude, and variation in amplitude between successive oscillations. The 27.5 grams of alcohol taken in a liter of solution are found to decrease the speed approximately 2 per cent, decrease the amplitude by a varying amount (about 15 per cent as an average) and to increase the variability roughly 50 per cent in the 2 hours after the ingestion of alcohol. The three features measured are certainly not independent of each other. We have no other data at hand with which to make any comparison. Perhaps any reduction in the average amplitude of such movements produces a larger percentage variability. Possibly the effort to keep up the speed operates also in the same direction. However this may be, the results taken at face value indicate that the alcohol produces a definite but rather slight decrement in speed, while smoothness and easy facility of the performance are strikingly interfered with. The results of this simple motor-coordination test are very similar to those found in the typewriting studies as to the effect of the alcohol upon the quality and smoothness of the work.

Eye Movements.

The data for the eye movements are recorded in the tables in 0.001 second. As in the typewriting experiments, the averages for the adductive (left) and the abductive (right) movements are given separately, since the two events are of different lengths and the effect of the alcohol is usually stronger upon one than upon the other. The technique used for this measurement was much the same as that employed by Dodge and Benedict, and as modified is described in brief on page 15.

Adductive Eye Movements.

The normal duration of the adductive horizontal eye movement is very uniformly 92 σ. (See table 43.) The velocity becomes somewhat slower following the control solution and with the prolongation of the experimental period, averaging about 96 σ. Following the alcohol dose, however, the movement is even slower than after the control dose, averaging about 102 σ. All three series, water-alcohol, beer-alcohol, and grape-juice-alcohol of 1919, give clear-cut alcohol effects, with maxima appearing in the fourth or fifth period which amount to a reduction in speed of roughly 8 per cent. The average effects in the first three alcohol series in order are +6.2, +7.9, and +5.1 per cent for the 2 hours following ingestion of the alcohol.

The chart (fig. 14) shows the data for adductive eye movement in the fourth series, that with grape juice and alcohol in 1920, which are not included in the results for *Mow* given in Chapter VI. The curves marked control and alcohol give the averages for both the preliminary periods and

TABLE 43.—*Effect of dilute alcohol on the duration of eye movement (adductive).*

[Values given in 0.001 second.]

Series, type, and date of experiments.	Average velocity at successive half-hours.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Water-alcohol series, 1919:	σ	σ	σ	σ	σ	σ	σ
Control: Nov. 5	93	94	97	97	94	....	96
Nov. 8	92	94	95	98	96	....	96
Nov. 19	91	94	95	97	98	....	97
Nov. 21	94	93	95	95	96	....	95
Nov. 22	91	92	96	99	95	....	97
Averages	**92**	**93**	**96**	**97**	**96**	....	**96**
Differences	(92)		+4	+ 5	+ 4	....	+ 4
Alcohol: Nov. 6	88	93	102	101	103	....	102
Nov. 7	94	93	98	98	104	....	100
Nov. 10	90	92	97	105	103	....	102
Nov. 17	93	94	102	107	108	....	106
Nov. 18	94	97	102	106	110	....	106
Averages	**92**	**94**	**100**	**103**	**106**	....	**103**
Differences	(93)		+7	+10	+13	....	+10
Effect in differences	......	......	+3	+ 5	+ 9	....	+ 6
Effect in per cent	(92)		+3.3	+ 5.4	+ 9.8	....	+ 6.2
Beer-alcohol series, 1919:							
Control: Dec. 4	90	93	93	94	97	97	95
Dec. 5	90	93	95	95	98	93	95
Dec. 10	92	93	93	93	94	92	93
Dec. 11	91	93	95	99	94	99	97
Averages	**91**	**93**	**94**	**95**	**96**	**95**	**95**
Differences	(92)		+2	+ 3	+ 4	+ 3	+ 3
Alcohol: Dec. 3	92	92	101	101	103	100	101
Dec. 8	91	91	104	102	108	104	105
Dec. 9	92	93	99	106	103	103	103
Dec. 13	93	92	100	105	99	101	101
Averages	**92**	**92**	**101**	**103**	**103**	**102**	**102**
Differences	(92)		+9	+11	+11	+10	+10
Effect in differences	......	......	+7	+ 8	+ 7	+ 7	+ 7
Effect in per cent	(92)		+7.6	+ 8.7	+ 7.6	+ 7.6	+ 7.9
Grape-juice-alcohol series, 1919:							
Control: Dec. 2	98	92	96	98	97	100	98
Dec. 16	91	89	93	95	97	96	95
Dec. 20	92	92	97	98	101	95	98
Averages	**94**	**91**	**95**	**97**	**98**	**97**	**97**
Differences	(92)		+3	+ 5	+ 6	+ 5	+ 5
Alcohol: Dec. 1	92	94	100	103	103	102	102
Dec. 15	92	93	99	105	100	100	101
Dec. 17	91	92	103	104	102	102	103
Dec. 18	94	91	97	101	102	101	100
Averages	**92**	**92**	**100**	**103**	**102**	**101**	**102**
Differences	(92)		+8	+11	+10	+ 9	+10
Effect in differences	......	......	+5	+ 6	+ 4	+ 4	+ 5
Effect in per cent	(92)		+5.4	+ 6.5	+ 4.3	+ 4.3	+ 5.1

those following the respective doses. For the actual values, reference must be made to the extreme left-hand scale. It is clear that the velocity is slower after the alcohol, the average effects upon the duration of the movement for the four periods after the dose being 6.3, 10.4, 5.2, and 5.2 per cent.

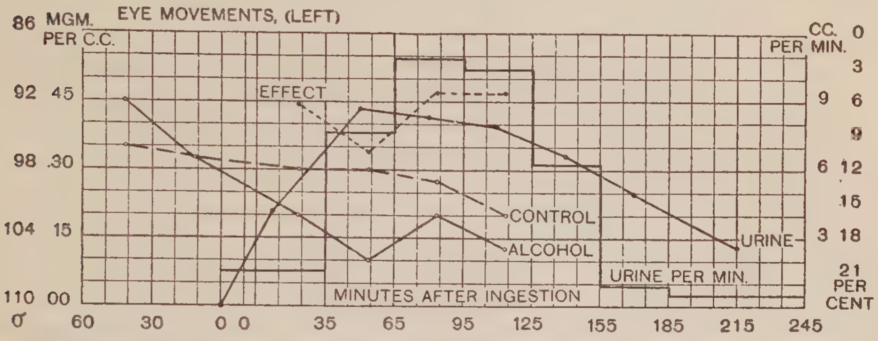

Fig. 14.—Effect of Alcohol on Velocity of Adductive Eye Movement at 30-minute Intervals After Ingestion Compared with Concentration of Alcohol in Urine. (Grape-juice-alcohol Series, 1920, Subject *Mow.*)

The maximum appears in the fourth period. This corresponds to the interval when the alcohol was at its highest concentration in the urine as shown by the urine curve in figure 14.

A chart for the corresponding results in the fifth or cider-alcohol series will be found in figure 15. The control and alcohol values in the two preliminary periods for each group of data are closely the same. Following the control solution, the averages gradually decline, showing a slower velocity, but the two curves in the chart indicate a much more prominent decline following the alcohol dose. In the "effect" curve for this cider-alcohol series, the maximum occurs in the fifth period (10.2 per cent). This seems to be somewhat later than the maximal concentration in the urine.

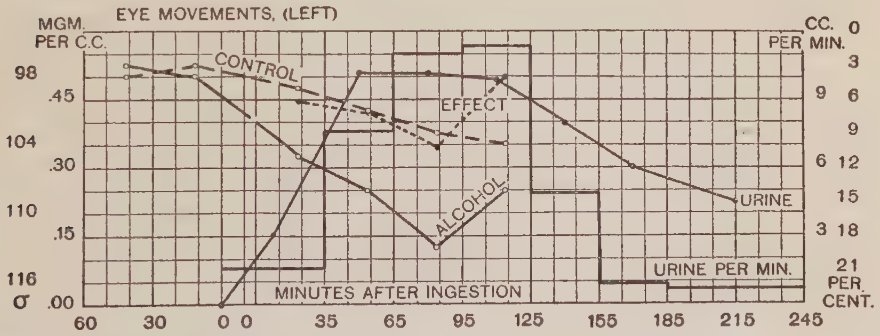

Fig. 15.—Effect of Alcohol on Velocity of Adductive Eye Movement at Intervals of 30 Minutes After Ingestion Compared with Concentration of Alcohol in Urine. (Cider-alcohol Series, 1920, Subject *Mow.*)

The general finding is that all five series give concordant results for the alcohol effect upon the adductive eye movement (left). The average percentage effect in each of the four periods following the alcohol in these five series are 5.7, 7.6, 7.4, and 5.3, respectively, with a total average lengthen-

TABLE 44.—*Effect of dilute alcohol on the duration of eye movement (abductive).*

[Values given in 0.001 second.]

Series, type, and date of experiments.	Average velocity at successive half-hours.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Water-alcohol series, 1919:	σ	σ	σ	σ	σ	σ	σ
Control: Nov. 5	82	88	92	93	92	....	92
Nov. 8	84	87	88	93	90	....	90
Nov. 19	85	86	84	89	90	....	88
Nov. 21	84	87	93	92	89	....	91
Nov. 22	85	87	91	92	87	....	90
Averages	**84**	**87**	**90**	**92**	**90**	....	**91**
Differences	(85)		+5	+7	+ 5	....	+ 6
Alcohol: Nov. 6	83	91	95	92	97	....	95
Nov. 7	82	84	93	93	93	....	93
Nov. 10	89	85	93	91	99	....	94
Nov. 17	84	85	89	95	97	....	94
Nov. 18	83	88	95	98	97	....	97
Averages	**84**	**87**	**93**	**94**	**97**	....	**95**
Differences	(85)		+8	+9	+12	....	+10
Effect in differences	......	......	+3	+2	+ 7	....	+ 4
Effect in per cent	(85)		+3.5	+2.3	+ 8.2	....	+ 4.7
Beer-alcohol series, 1919:							
Control: Dec. 4	85	88	90	90	91	91	91
Dec. 5	88	88	92	91	92	92	92
Dec. 10	83	86	90	90	91	90	90
Dec. 11	86	89	90	93	92	90	91
Averages	**85**	**88**	**90**	**91**	**91**	**91**	**91**
Differences	(86)		+4	+5	+ 5	+5	+ 5
Alcohol: Dec. 3	86	89	95	95	98	94	96
Dec. 8	84	84	94	95	92	98	95
Dec. 9	85	92	95	100	94	94	96
Dec. 13	89	89	99	96	104	94	98
Averages	**86**	**88**	**96**	**96**	**97**	**95**	**96**
Differences	(87)		+9	+9	+10	+8	+ 9
Effect in differences	......	......	+5	+4	+ 5	+3	+ 4
Effect in per cent	(86)		+5.8	+4.6	+ 5.8	+3.5	+ 4.9
Grape-juice-alcohol series, 1919:							
Control: Dec. 2	85	87	89	88	91	92	90
Dec. 16	86	89	89	93	91	91	91
Dec. 20	87	87	94	89	89	89	90
Averages	**86**	**88**	**91**	**90**	**90**	**91**	**91**
Differences	(87)		+4	+3	+ 3	+4	+ 4
Alcohol: Dec. 1	87	84	91	92	98	98	95
Dec. 15	89	91	97	97	96	97	97
Dec. 17	84	86	96	99	92	93	95
Dec. 18	87	89	101	97	99	96	98
Averages	**87**	**87**	**96**	**96**	**96**	**96**	**96**
Differences	(87)		+9	+9	+ 9	+9	+ 9
Effect in differences	......	......	+5	+6	+ 6	+5	+ 6
Effect in per cent	(87)		+5.7	+6.9	+ 6.9	+5.7	+ 6.3

ing of the eye movement following the alcohol of 6.6 per cent (slower horizontal velocity).

ABDUCTIVE EYE MOVEMENTS.

For subject *Mow,* the abductive movements are considerably quicker than the adductive movements, being normally 85 to 87 σ, as compared with approximately 92 σ for apparently the same amplitude. The data obtained in the five alcohol series for the measurement of the abductive movement are shown in table 44 and figures 16 and 17, which are similar to those just discussed. The data are exceedingly regular. It may be noted that in every period following the control solution in all five series, the eye velocity (abductive) is slower than the rate in the corresponding preliminary average. Following alcohol, however, the rate is still slower, so that every percentage for alcohol effect in the five series is plus in direction (slower movement). The effect as given in figure 16 for the fourth series appears a little irregular, in that it is at maximum in period 3, which is prior to the maximal concentration in the urine. The average increases for the five series are 4.7, 4.9, 6.3, 5.9, and 6.6 per cent, with a grand average increase in the time required for the movement during the 2-hour period following alcohol of 5.7 per cent.

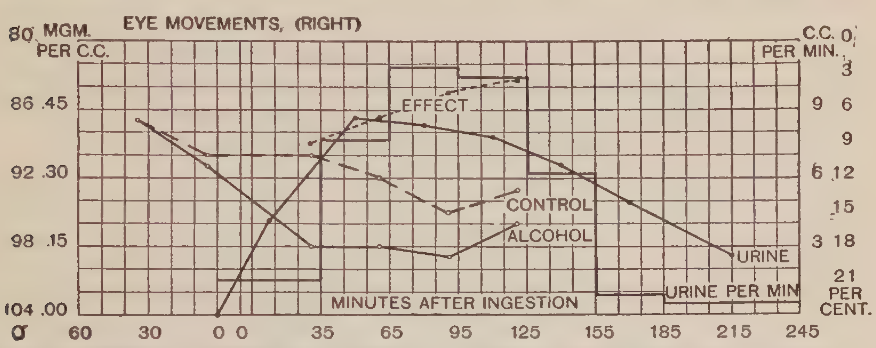

FIG. 16.—Effect of Alcohol on Velocity of Abductive Eye Movement at 30-minute Intervals After Ingestion Compared with Alcohol Concentration in Urine. (Grape-juice-alcohol Series, 1920, Subject *Mow.*)

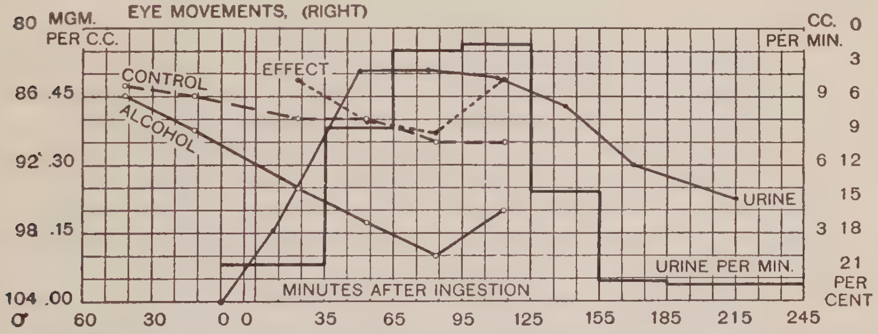

FIG. 17.—Effect of Alcohol on Velocity of Abductive Eye Movement at 30-minute Intervals After Ingestion Compared with Alcohol Concentration in Urine. (Cider-alcohol Series, 1920, Subject *Mow.*)

The clear-cut effect of ethyl alcohol on the velocity of the eye movement and the regularity with which this effect is produced following the ingestion of the beverage was pointed out in the publication of Dodge and Benedict. The data just reviewed stand as a striking confirmation of the soundness of their observation. The special contribution of our data in this case is

TABLE 45.—*Effect of dilute alcohol on eye-hand coordination with pursuit pendulum.*

Series, type, and date of experiments.	Total catch at successive half-hours.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Water-alcohol series, 1919:	*c. c.*	*c. c.*	*c. c.*	*c. c.*	*c. c.*	*c. c.*	*c. c.*
Control: Nov. 5	1,142	1,120	1,115	1,145	1,120	....	1,127
Nov. 8	1,170	1,152	1,176	1,191	1,185	....	1,184
Nov. 19	1,190	1,184	1,192	1,200	1,190	....	1,194
Nov. 21	1,190	1,178	1,178	1,140	1,148	....	1,155
Nov. 22	1,200	1,180	1,200	1,193	1,192	....	1,195
Averages	**1,178**	**1,162**	**1,172**	**1,174**	**1,167**	....	**1,171**
Differences	(1,170)		+ 2	+ 4	− 3	....	+ 1
Alcohol: Nov. 6	1,178	1,150	1,092	1,108	1,096	....	1,099
Nov. 7	1,156	1,166	1,137	1,122	1,066	....	1,108
Nov. 10	1,172	1,185	1,146	1,130	1,096	....	1,124
Nov. 17	1,173	1,173	1,130	1,043	1,065	....	1,079
Nov. 18	1,172	1,208	1,107	1,102	1,135	....	1,115
Averages	**1,170**	**1,176**	**1,122**	**1,101**	**1,092**	....	**1,105**
Differences	(1,173)		−51	−72	−81	....	−68
Effect in differences	....	....	−53	−76	−78	....	−69
Effect in per cent	(1,172)		− 4.5	− 6.5	− 6.7	....	− 5.9
Beer-alcohol series, 1919:							
Control: Dec. 4	1,212	1,220	1,202	1,227	1,216	1,220	1,216
Dec. 5	1,190	1,208	1,209	1,209	1,191	1,205	1,204
Dec. 10	1,201	1,213	1,210	1,221	1,218	1,215	1,216
Dec. 11	1,220	1,210	1,190	1,210	1,204	1,212	1,204
Averages	**1,206**	**1,213**	**1,203**	**1,217**	**1,207**	**1,213**	**1,210**
Differences	(1,209)		− 6	+ 8	− 2	+ 4	+ 1
Alcohol: Dec. 3	1,197	1,205	1,170	1,170	1,180	1,140	1,165
Dec. 8	1,213	1,214	1,160	1,172	1,139	1,166	1,159
Dec. 9	1,202	1,189	1,150	1,176	1,160	1,158	1,161
Dec. 13	1,172	1,188	1,184	1,180	1,200	1,160	1,181
Averages	**1,196**	**1,199**	**1,166**	**1,174**	**1,170**	**1,156**	**1,167**
Differences	(1,197)		−31	−23	−27	−41	−31
Effect in differences	....	....	−25	−31	−25	−45	−32
Effect in per cent	(1,203)		− 2.1	− 2.6	− 2.1	− 3.7	− 2.6
Grape-juice-alcohol series, 1919:							
Control: Dec. 2	1,195	1,217	1,210	1,205	1,205	1,204	1,206
Dec. 16[1]	906	894	821	912	910	925	892
Dec. 20[1]	945	940	910	896	894	920	905
Averages	**1,015**	**1,017**	**980**	**1,004**	**1,003**	**1,016**	**1,001**
Differences	(1,016)		−36	−12	−13	± 0	−15
Alcohol: Dec. 1	1,203	1,188	1,175	1,140	1,118	1,135	1,142
Dec. 15[1]	890	805	812	745	803	808	792
Dec. 17[1]	890	965	818	896	874	931	880
Dec. 18[1]	983	937	896	890	858	923	892
Averages	**991**	**974**	**925**	**918**	**913**	**949**	**926**
Differences	(982)		−57	−64	−69	−33	−56
Effect in differences	....	....	−21	−52	−56	−33	−41
Effect in per cent	(999)		− 2.1	− 5.2	− 5.6	− 3.3	− 4.1

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[1] Beginning with December 15, *Mow* was always tested with cups having a diameter of 9.5 mm. at the opening.

that the typical effect, and one of about the usual magnitude found in Dodge and Benedict's experiments with dose A, and in our own experiments with dose A in the alcohol typewriting series, appears here when the alcohol, 27.5 grams, is so diluted as to form but 2.75 per cent of the solution. Moreover, the effect is sensibly of the same size, irrespective of the character of the liquid with which the alcohol is diluted.

Eye-Hand Coordination with Pursuit Pendulum.

This series with the trained subject *Mow* was the first study in which the pursuit pendulum was used to test the motor coordination after alcohol. The technique is described on page 16. The values are given in terms of the total amount of water collected in the test in the 25 cups. If all the liquid were caught on each swing of the pendulum, it was theoretically possible to have a score of 1,250 c. c. It is seen from the values for periods 1 and 2 of the water-alcohol series in table 45 that the usual normal score for this subject is about 1,170 c. c. of liquid for the 25 catches. In the first two series the cups were used with the full-sized opening of 19 mm. The subject was catching so nearly the full amount that the test was not sufficiently difficult. Beginning with December 15, 1919, in the third series, a collar to reduce the opening at the mouth of the cup to a diameter of 9.5 mm. was always inserted by the subject when each cup was used. This added but slightly to the routine and made it a more satisfactorily difficult test.

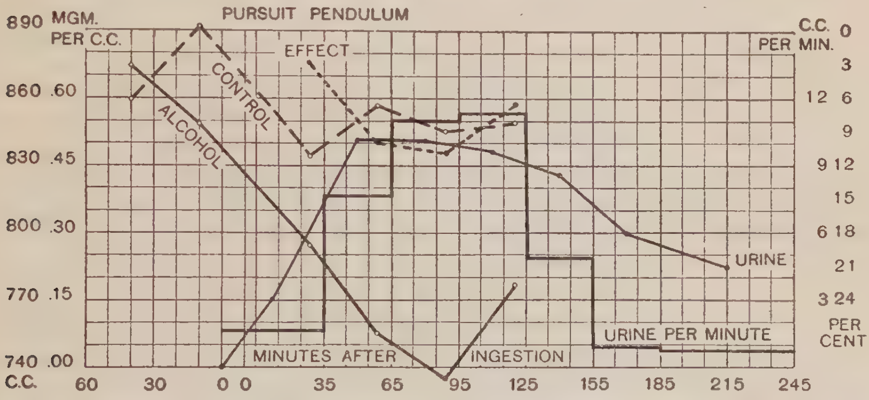

FIG. 18.—Effect of Alcohol on Adequacy of Coordinations Measured with Pursuit Pendulum at 30-minute Intervals After Ingestion Compared with Alcohol Concentration in Urine. (Cider-alcohol Series, 1920, Subject *Mow.*)

The scores after the control solution was taken were but slightly above or below those for the preliminary period. After the alcohol, the scores were usually smaller than in the preliminary period. Thus, the alcohol effect for the three series shown in table 45 is always minus in direction, with average decreases of 5.9, 2.6, and 4.1 per cent in efficiency.[a] The grape-juice-alcohol series of 1920 (see page 249) is exceptional in that not all of the percentage effects after the alcohol dose are minus in direction. The averages for the four periods are +1.8, −10.0, −8.6, and +1.3 per cent, with an average for the 2 hours of −3.9 per cent. The average is

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[a] In this latter series (grape-juice-alcohol of 1919) a complication arises from the fact that in one of the three control experiments, December 2, the wide-mouth cups were used and this was also the case in one of the four alcohol experiments, that of December 1. If the alcohol effect be computed for only those days when the cups with the reduced opening were used, the percentage decreases for periods 3 to 6 are found to be −1.5, −5.5, −5.1, −2.8, which average −3.7. If the results are computed for the pair of days December 2 and December 1, the average effect amounts to a decrease of 4.5 per cent after alcohol.

TABLE 46.—*Effect of dilute alcohol on variability in pursuit-pendulum test.*

Series, type, and date of experiments.	Coefficient of variability at successive half-hours.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Water-alcohol series, 1919:	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*
Control: Nov. 5	6.5	10.0	8.0	7.2	7.7	....	7.6
Nov. 8	6.4	8.8	4.2	3.6	4.2	....	4.0
Nov. 19	4.6	2.9	6.2	4.1	3.5	....	4.6
Nov. 21	2.1	4.2	3.6	7.6	8.0	....	6.4
Nov. 22	2.9	5.6	2.9	2.9	3.6	....	3.1
Averages	**4.5**	**6.3**	**5.0**	**5.1**	**5.4**	....	**5.1**
Differences	(5.4)		− 0.4	− 0.3	± 0.0	....	− 0.2
Alcohol: Nov. 6	3.6	3.7	11.6	7.5	10.2	....	9.8
Nov. 7	8.8	6.0	6.9	11.7	12.5	....	10.4
Nov. 10	6.0	4.2	8.1	8.7	7.5	....	8.1
Nov. 17	4.2	4.7	6.9	10.8	9.3	....	9.0
Nov. 18	5.6	2.9	8.4	8.4	6.5	....	7.8
Averages	**5.6**	**4.3**	**8.4**	**9.4**	**9.2**	....	**9.0**
Differences	(5.0)		+ 3.4	+ 4.4	+ 4.2	....	+ 4.0
Effect in differences	......	......	+ 3.8	+ 4.7	+ 4.2	....	+ 4.2
Effect in per cent	(5.2)		+73.1	+90.4	+80.8	....	+81.4
Beer-alcohol series, 1919:							
Control: Dec. 4	2.1	2.0	4.6	2.0	4.4	2.9	3.5
Dec. 5	4.6	3.5	0.5	2.9	4.6	5.0	3.1
Dec. 10	2.9	4.5	2.1	7.5	4.1	4.9	4.7
Dec. 11	2.0	3.5	3.5	2.9	4.1	5.3	4.0
Averages	**2.9**	**3.4**	**2.6**	**3.8**	**4.3**	**4.5**	**3.8**
Differences	(3.2)		− 0.6	+ 0.6	+ 1.1	+ 1.3	+ 0.6
Alcohol: Dec. 3	4.6	2.1	6.8	7.0	3.6	5.7	5.8
Dec. 8	4.1	4.1	7.7	6.8	10.1	7.0	7.9
Dec. 9	5.4	2.9	8.4	4.6	6.4	7.5	6.7
Dec. 13	6.4	6.8	2.1	3.0	4.2	9.1	4.6
Averages	**5.1**	**4.0**	**6.3**	**5.4**	**6.1**	**7.3**	**6.3**
Differences	(4.6)		+ 1.7	+ 0.8	+ 1.5	+ 2.7	+ 1.7
Effect in differences	......	......	+ 2.3	+ 0.2	+ 0.4	+ 1.4	+ 1.1
Effect in per cent	(3.9)		+59.0	+ 5.1	+10.2	+35.9	+27.6
Grape-juice-alcohol series, 1919:							
Control: Dec. 2	6.3	2.0	4.1	2.1	6.2	3.5	4.0
Dec. 16[1]	19.5	18.3	20.0	14.2	13.7	14.8	15.7
Dec. 20[1]	15.6	12.8	14.3	10.9	18.7	12.4	14.1
Averages	**13.8**	**11.0**	**12.8**	**9.1**	**12.9**	**10.2**	**11.3**
Differences	(12.4)		+ 0.4	− 3.3	+ 0.5	− 2.2	− 1.2
Alcohol: Dec. 1	2.1	2.9	5.1	6.5	7.7	7.2	6.6
Dec. 15[1]	15.4	14.9	18.1	21.3	16.0	17.2	18.2
Dec. 17[1]	17.4	12.2	21.8	14.2	16.6	14.2	16.7
Dec. 18[1]	9.4	11.3	15.9	20.7	16.6	13.2	16.6
Averages	**11.1**	**10.3**	**15.2**	**15.7**	**14.2**	**13.0**	**14.5**
Differences	(10.7)		+ 4.5	+ 5.0	+ 3.5	+ 2.3	+ 3.8
Effect in differences	......	......	+ 4.1	+ 8.3	+ 3.0	+ 4.5	+ 5.0
Effect in per cent	(11.6)		+35.3	+71.5	+25.8	+38.8	+42.9

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[1] Beginning with December 15, *Mow* was tested with cups having a diameter of 9.5 mm. at the opening.

TABLE 46.—*Effect of dilute alcohol on variability in pursuit-pendulum test*—Continued.

Series, type, and date of experiments.	Coefficient of variability at successive half-hours.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Grape-juice-alcohol series, 1920:	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*
Control: Dec. 8	15.9	12.7	21.0	16.3	15.4	16.1	17.2
Dec. 11	12.6	12.3	11.4	11.8	16.4	20.1	14.9
Averages	14.3	12.5	16.2	14.1	15.9	18.1	16.1
Differences	(13.4)		+ 2.8	+ 0.7	+ 2.5	+ 4.7	+ 2.7
Alcohol: Dec. 9	13.7	13.7	15.9	14.7	17.9	18.5	16.8
Dec. 10	13.8	17.9	14.2	25.5	20.7	19.4	20.0
Averages	13.8	15.8	15.1	20.1	19.3	19.0	18.4
Differences	(14.8)		+ 0.3	+ 5.3	+ 4.5	+ 4.2	+ 3.6
Effect in differences	......	......	− 2.5	+ 4.6	+ 2.0	− 0.5	+ 0.9
Effect in per cent	(14.1)		−17.7	+32.6	+14.2	− 3.5	+ 6.4
Cider-alcohol series, 1920:							
Control: Dec. 15[1]	12.4	16.5	15.4	15.0	11.7	10.7	13.2
Dec. 18[1]	15.1	12.1	18.3	11.0	14.3	14.6	14.6
Dec. 22[1]	13.5	15.1	12.0	12.5	15.8	13.1	13.4
Averages	13.7	14.6	15.2	12.8	13.9	12.8	13.7
Differences	(14.2)		+ 1.0	− 1.4	− 0.3	− 1.4	− 0.5
Alcohol: Dec. 13	16.2	16.1	17.3	18.8	19.6	17.3	18.3
Dec. 16[1]	15.2	17.2	19.2	21.9	21.0	15.2	19.3
Dec. 17[1]	14.9	15.2	14.4	17.9	17.7	16.5	16.6
Dec. 20[1]	12.5	13.2	16.0	18.2	23.6	16.4	18.5
Averages	14.7	15.4	16.7	19.2	20.5	16.4	18.2
Differences	(15.1)		+ 1.6	+ 4.1	+ 5.4	+ 1.3	+ 3.1
Effect in differences	......	......	+ 0.6	+ 5.5	+ 5.7	+ 2.7	+ 3.6
Effect in per cent	(14.7)		+ 4.1	+37.4	+38.6	+18.4	+24.6

[1] Beginning with December 15, *Mow* was tested with cups having a diameter of 9.5 mm. at the opening.

fairly near to that for the preceding series. This is to be accounted for by the stronger and maximal effect in period 4. The results for the cider-alcohol series are shown in diagrammatic form in figure 18. There was considerable discrepancy between the values for the second preliminary periods on the control and alcohol days, and the difference in level between the control and alcohol performance is not more conspicuous in period 3 than in period 2, but in the remainder of the tests, that is, in periods 4, 5, and 6, the catch after alcohol was much below that after the control dose. The effect is a little more prominent in period 5 than in 4 and considerably stronger in both these than in 3 or 6. The average for the cider-alcohol series is a decreased ability of 7.6 per cent, which is the most marked effect shown in any average for this measurement in the five series.

In the pursuit-pendulum test as given to *Mow* in these five series in which 30-minute periods were used, the individual catch was always measured. We have taken advantage of this fact to compute the coefficient of variability; the data are presented for the 5 series in table 46. In this instance the coefficient of variability has been computed by first finding the standard deviation for the 25 catches, and then dividing this by the average catch for the period to obtain the percentage variation. In the first two series (water-alcohol and beer-alcohol), when the cups were used with the full-sized opening and the subject was able to catch nearly all of the expelled liquid, the normal percentage variation is small, i. e., from 3 to 5 per cent. In the three later series, when the reducer was always used with the cups, so that the subject caught less liquid and was forced to coordinate with greater accuracy, the percentage variability is usually about 12 to 14 per cent. The variability is, for the most part, consistently in the direction of an increase after alcohol. This increase is particularly large in the first series (that with water and alcohol in 1919) in which the maximal variability which occurs in period 4 increases 90 per cent; the average increase in the three periods is 81 per cent. The beer and alcohol series shows some irregularity in that the percentage effects, while all plus, are relatively small in periods 4 and 5. The average for the four periods is +27.6 per cent. The grape-juice series of 1919 likewise shows a maximum in the fourth period, in this case, 71.5 per cent. The average for the four periods is an increase in variability of 42.9 per cent.[a] The grape-juice-alcohol series of 1920, as was found with the results for the total catch, shows a fairly marked alcohol effect upon the variability in periods 4 and 5, where the maximum alcohol effect usually occurs, but results in the opposite direction appear in periods 3 and 6. The maximal alcohol effect is in period 4, with an increase of 32.6 per cent. The average for the four periods following the dose is +6.4 per cent. In the cider-alcohol series the results are all plus, with about the same intensity in periods 4 and 5, that is, approximately 37 per cent, and a total average of about 25 per cent more variation.

This neuro-muscular test which measures the coordination of eye and hand by the simple method of observing how much liquid a subject can catch from a swinging pendulum, has not previously been used in alcohol experimentation. We find that even when every advantage is allowed the subject by letting him give the signal for the pendulum to be released and thus set his own pace, the dilute alcohol measurably and uniformly affects his efficiency. The amount of liquid that he is able to catch is reduced on the average about 5 per cent during the 2 hours following the ingestion of 27.5 grams of alcohol in a liter of solution, and the smoothness or regularity of coordination between successive trials is reduced somewhat more than 30 per cent on the average. The alcohol effect in this case is therefore measurable, and if the task were a factory process, it would probably be considered large enough to have practical importance in reference to the working efficiency of the subject. Further alcohol data for the pursuit pendulum will be presented in Chapter VI.

CONTINUOUS COORDINATION WITH PURSUITMETER.

The pursuitmeter, like the pursuit pendulum, was first used with *Mow* in this group of alcohol studies. A description of the apparatus and the method of use may be found on page 19. While the equipment may seem quite complex, it is the merit of the pursuitmeter that it provides fairly uncomplicated results. The time and error scores which are always concerned in any measurement of coordination are, in this case, electrically integrated in what is believed to be a perfectly logical weighting of each. One has, therefore, at the end of the test, simply to read the revolutions on the two integrating meters and obtain the total of their scores.

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[a] When the computation of the alcohol effect is made solely from the data for the days when the narrow cup-opening was used, the percentages for periods 3 to 6 are +30, +61, +22, and +29, with an average increase in variability of 36 per cent. The average increase for the pair of experiments, December 1 and December 2, is 132 per cent.

TABLE 47.—*Effect of dilute alcohol on continuous coordination with pursuitmeter.*

[Unit of measurement, 0.01 revolution on meter dials.]

Series, type, and date of experiments.	Total score at successive half-hours.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Water-alcohol series, 1919:							
Control: Nov. 5	460	436	456	450	477	....	461
Nov. 8	407	370	395	386	381	....	387
Nov. 19	365	357	339	335	399	....	358
Nov. 21	426	378	342	362	382	....	362
Nov. 22	354	341	346	331	317	....	331
Averages	**402**	**376**	**376**	**373**	**391**	....	**380**
Differences	(389)		−13	−16	+ 2	....	− 9
Alcohol: Nov. 6	436	424	447	449	467	....	454
Nov. 7	417	378	380	442	446	....	423
Nov. 10	390	374	393	419	424	....	412
Nov. 17	398	387	423	428	445	....	432
Nov. 18	367	320	416	398	417	....	410
Averages	**402**	**377**	**412**	**427**	**440**	....	**426**
Differences	(389)		+23	+38	+51	....	+37
Effect in differences	....	....	+36	+54	+49	....	+46
Effect in per cent	(389)		+ 9.3	+13.9	+12.6	....	+11.9
Beer-alcohol series, 1919:							
Control: Dec. 4	350	373	333	357	307	345	336
Dec. 5	366	375	359	329	373	331	348
Dec. 10	319	307	284	330	301	301	304
Dec. 11	315	325	321	331	323	333	327
Averages	**338**	**345**	**324**	**337**	**326**	**328**	**329**
Differences	(341)		−17	− 4	−15	−13	−12
Alcohol: Dec. 3	329	325	342	373	389	403	377
Dec. 8	343	335	359	429	402	411	400
Dec. 9	314	330	340	425	389	369	381
Dec. 13	352	316	340	442	424	440	412
Averages	**334**	**326**	**345**	**417**	**401**	**406**	**392**
Differences	(330)		+15	+87	+71	+76	+62
Effect in differences	....	....	+32	+91	+86	+89	+75
Effect in per cent	(335)		+ 9.5	+27.2	+25.7	+26.6	+22.3
Grape-juice-alcohol series, 1919:							
Control: Dec. 2	352	357	337	319	366	357	345
Dec. 16	335	386	311	308	303	299	305
Dec. 20	322	269	301	282	271	300	289
Averages	**336**	**304**	**316**	**303**	**313**	**319**	**313**
Differences	(320)		− 4	−17	− 7	− 1	− 7
Alcohol: Dec. 1	355	389	387	422	421	438	417
Dec. 15	302	297	326	402	363	364	364
Dec. 17	295	291	297	334	339	301	318
Dec. 18	271	285	302	313	331	327	318
Averages	**306**	**315**	**328**	**368**	**363**	**357**	**354**
Differences	(310)		+18	+58	+53	+47	+44
Effect in differences	....	....	+22	+75	+60	+48	+51
Effect in per cent	(315)		+ 7.0	+23.8	+19.1	+15.2	+16.3

The totals for the experimental periods in the first three series on *Mow* are given in table 47. In the water-alcohol series the average for the first column of scores from the normal data, and likewise the average for the first preliminary period of the alcohol days, is 402. The average for the second group of data preceding the control dose is 376, and for the second preliminary period of the alcohol days is 377. Such identity is, of course, only accidental and can not be credited to the apparatus or to the technique. Even *Mow,* who, prior to these experiments, had received considerable practice on the pursuitmeter, shows improvement after the experiments began and during the succeeding series. The total average for the preliminary periods in the water-alcohol series is 389, in the beer-alcohol series, 335, and in the grape-juice-alcohol series of 1919, 315. Control and alcohol days were so interspersed within each series that the practice factor, while probably it exercises some influence on the results, does not seem to interfere with the comparison. Characteristically it is seen in these three series of experiments that the score following the control dose is smaller than in the preliminary period, thus indicating an increase in efficiency. The only exception to this rule is in period 5 of the water-alcohol series, in which the average difference is +2. In contrast to the better score after the control solution, the scores are regularly poorer after the alcohol in all three series. The effect of the alcohol was least marked in the first series. The maximal effect here was a decreased efficiency of 13.9 per cent in the fourth period, that is, about 45 minutes after the alcohol was taken, and an average decrease in efficiency of 11.9 per cent for the three periods following the alcohol dose. In the beer-alcohol series and the grape-juice-alcohol series of 1919, the maximum effect likewise appears in the fourth period, being 27.2 per cent in the former and 23.8 per cent in the latter, and these series give averages of 22.3 and 16.3 per cent.

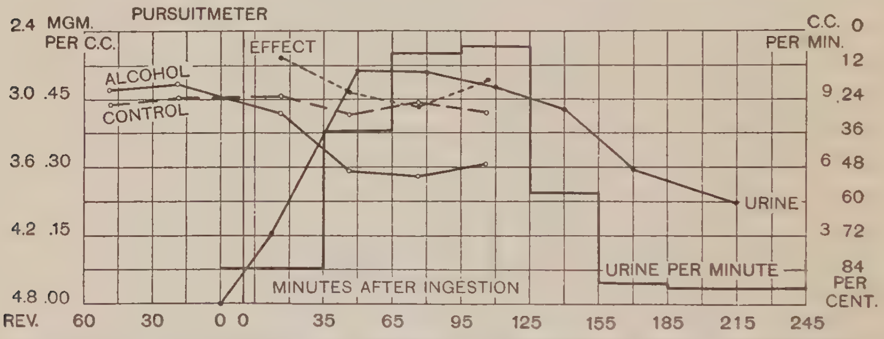

FIG. 19.—Effect of Alcohol on Adequacy of Performance with Pursuitmeter at 30-minute Intervals After Ingestion Compared with Alcohol Concentration in Urine. (Cider-alcohol Series, 1920, Subject *Mow.*)

In the grape-juice-alcohol series of 1920 for which the data are given in table 68, page 252, a slightly larger effect of the alcohol is found in period 5, being 23.7 per cent as against 22.4 per cent for period 4. All periods show decreased efficiency, with an average effect for the four of 19.1 per cent.

The comparable data for the cider-alcohol series are published in graphic form in figure 19. The alcohol and control preliminary periods, both normal performances, are closely the same, but following the doses, while the control values hardly change their level, the alcohol performance deteriorates quite appreciably. The maximal effect, as in the fourth series, is in period 5, and is 26.4 per cent as compared with 21.6 per cent in period 4. The average decrease in adequacy of coordination for this series is 18.4 per cent.

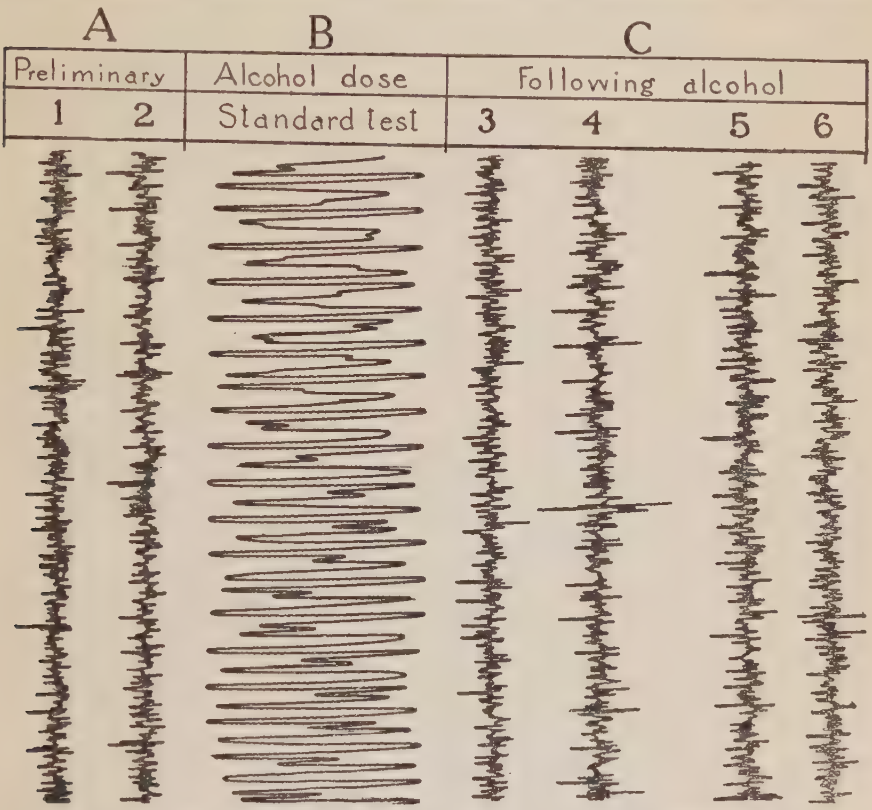

FIG. 20.—Illustrative Graphic Tracings from Pursuitmeter. These tracings are approximately normal size.

A, preliminary periods 1 and 2, previous to ingestion of alcohol.

B, standardizing test of the apparatus made in the interval when the subject was drinking the dose. This curve indicates the nature of the changes induced solely by the disturber. This, in other words, is the pattern of task set the subject.

C, Periods 3, 4, 5, and 6 following ingestion of alcohol. No. 4 shows most prominently the wider range (poorer compensation) following alcohol.

In the description of the apparatus it is noted that the curve-drawing wattmeter produced a graphic record of the fluctuations between the two electric circuits. (See p. 23.) Graphic tracings were obtained in the measurements with the pursuitmeter for *Mow* as well as with the other subjects whose results are reported in Chapter VI. This was done simply as a matter of precaution, so that if a score were especially difficult to understand, the graphic record would serve as an added evidence of the situation. A series of such graphic records for one experimental day (December 9, 1920) with *Mow* is reproduced in figure 20. The tracing in each case seems to be made up of small horizontal movements that deviate closely around the hypothetical central line, which is usually covered by them. Between periods 2 and 3 the alcohol was taken and the instrument was standardized. In this interval the deflections were allowed to go entirely uncompensated, so that the nature of the deflections which the subject is regularly required to compensate can be seen in this tracing. In the four tracings which represent periods 3, 4, 5, and 6, after the alcohol was taken, there is a somewhat wider scatter, particularly in period 4. This shows that the compensations were less adequate. There are no radical prolonged departures from the zero-line shown by these tracings. At no time did this subject or any other subject whom we have used have such lapses of attention as seriously to interrupt the compensation. The graphic record would show exactly this feature by a large loop if the interruption continued very long. The paper was driven by clockwork at the rate of 1 inch per minute.

In previous discussion it has been mentioned that the pursuit-pendulum test allows the subject to give the signal, thereby permitting him to set his own pace and to pull himself together for action at just the moment that this is needed. In contrast to this discontinuous test, the pursuitmeter requires a continuing uninterrupted performance, and every moment counts. The pace is made for the subject. It is always, of course, the same, and he is required, in these experiments, to work continuously for 5 minutes. Our dilute dosage of alcohol was found to reduce the efficiency on the pursuit pendulum about 5 per cent. The percentage effect as shown by the alcohol with the pursuitmeter test is a decrease in efficiency of about 18 per cent as an average for the five series. Considering the nature of the test and its fundamental similarity to many industrial tasks, the alcohol effect is of such an amount as to be of practical significance. The pursuitmeter was used in the succeeding experiments, and further data are found in the second part of this chapter and also in Chapter VI.

EYE REACTIONS.[a]

A brief description of the technique for this measure is given on page 13, with reference to more detailed description. The trained subject, *Mow*, had received considerable preliminary experience with the measurements of eye reactions. Notwithstanding this fact, the change due to practice may be clearly seen by comparison of the average value for the preliminary periods in the water-alcohol series, 164 σ, with that for the succeeding beer-alcohol series, 152 σ, and the grape-juice-alcohol series of 1919 or 145 σ. The detailed results for these three series are given in table 48. The effect of the alcohol is in the direction of a slower reaction time, but the results are not uniform from series to series. In the water-alcohol series there is no well-defined maximum for the three periods, the average of which is +1.6 per cent. In the beer-alcohol series the maximal effect was in period 3, with an increase in reaction time of 11.8 per cent. There were smaller percentages in periods 4 and 5, and again a larger increase (8.6 per cent) in period 6. The average for the four periods was a slower reaction of 8.2 per cent. In the third series (the grape-juice-alcohol series of 1919) the effect of alcohol is not so large as in the second series. The maximum of 9.0 per cent is found in period 4; the average for all of the periods after alcohol is +5.7 per cent. In the two charts, figures 21 and 22, which show the eye-reaction results for the grape-juice-alcohol series of 1920 and the cider-alcohol series of 1920, the average values for the control and alcohol curves

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[a] The turning of the eye to a new point of regard is often designated "fixation reflex" in physiological literature.

TABLE 48.—*Effect of dilute alcohol on speed of eye reaction to peripheral stimuli.*

Series, type, and date of experiments.	Average reaction time at successive half-hours.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Water-alcohol series, 1919:	σ	σ	σ	σ	σ	σ	σ
Control: Nov. 5	195	190	181	203	190	....	191
Nov. 8	175	153	174	167	169	....	170
Nov. 19	138	160	163	164	155	....	161
Nov. 21	152	154	154	153	156	....	154
Nov. 22	150	163	173	168	160	....	167
Averages	**162**	**164**	**169**	**171**	**166**	....	**169**
Differences	(163)		+ 6	+ 8	+ 3	....	+ 6
Alcohol: Nov. 6	185	190	181	184	189	....	185
Nov. 7	158	179	179	180	179	....	179
Nov. 10	179	158	164	168	168	....	167
Nov. 17	150	150	181	158	154	....	164
Nov. 18	150	142	162	174	167	....	168
Averages	**164**	**164**	**173**	**173**	**171**	....	**172**
Differences	(164)		+ 9	+ 9	+ 7	....	+ 8
Effect in differences	....	....	+ 3	+ 1	+ 4	....	+ 3
Effect in per cent	(164)		+ 1.8	+ 0.6	+ 2.4	....	+ 1.6
Beer-alcohol series, 1919:							
Control: Dec. 4	152	142	147	152	162	154	154
Dec. 5	162	148	140	152	154	145	150
Dec. 10	158	154	151	154	152	149	152
Dec. 11	143	150	152	139	146	145	146
Averages	**154**	**148**	**147**	**149**	**153**	**148**	**149**
Differences	(151)		− 4	− 2	+ 2	− 3	− 2
Alcohol: Dec. 3	152	158	170	153	166	172	165
Dec. 8	141	148	161	161	163	158	161
Dec. 9	148	155	165	161	161	166	163
Dec. 13	166	167	175	174	169	159	169
Averages	**152**	**157**	**168**	**162**	**165**	**164**	**165**
Differences	(154)		+14	+ 8	+11	+10	+11
Effect in differences	....	....	+18	+10	+ 9	+13	+13
Effect in per cent	(152)		+11.8	+ 6.6	+ 5.9	+ 8.6	+ 8.2
Grape-juice-alcohol series, 1919:							
Control: Dec. 2	156	156	163	160	168	170	165
Dec. 16	144	142	150	149	156	150	151
Dec. 20	145	150	151	152	148	161	153
Averages	**148**	**149**	**155**	**154**	**157**	**160**	**157**
Differences	(148)		+ 7	+ 6	+ 9	+12	+ 9
Alcohol: Dec. 1	138	149	159	177	168	168	168
Dec. 15	144	147	156	165	165	illeg.	162
Dec. 17	140	137	160	149	151	147	152
Dec. 18	141	146	160	156	164	152	158
Averages	**141**	**145**	**159**	**162**	**162**	**156**	**160**
Differences	(143)		+16	+19	+19	+13	+17
Effect in differences	....	....	+ 9	+13	+10	+ 1	+ 8
Effect in per cent	(145)		+ 6.2	+ 9.0	+ 6.9	+ 0.7	+ 5.7

indicate much more irregularity than is usual with our other measurements. In general, the alcohol performance is below that indicated by the control data, except in period 4 in figure 21.

The eye reaction as a measurement seems to give variable results in successive uses of it in alcohol experimentation. Dodge and Benedict[a] found that the eye-reaction data presented unique difficulties from the standpoint of technique and explanation of results. The writer has seriously tried to improve the technique by providing a larger number of stimulus positions, so that subjects may not anticipate the direction or location of the stimulus from the preliminary fixation-mark. We have likewise used a subject who was thought to be well practiced in the tests. Furthermore, it seems logical to assume that the eye reaction should be well practiced by the regular experiences of everyday life. With all these precautions, the eye-reaction results still show certain irregularities, but it seems clear that the typical alcohol effect is in the direction of a slower fixation response. Four out of the five series indicate a lengthening in reaction time as the average effect, and even the exceptional series (the grape-juice-

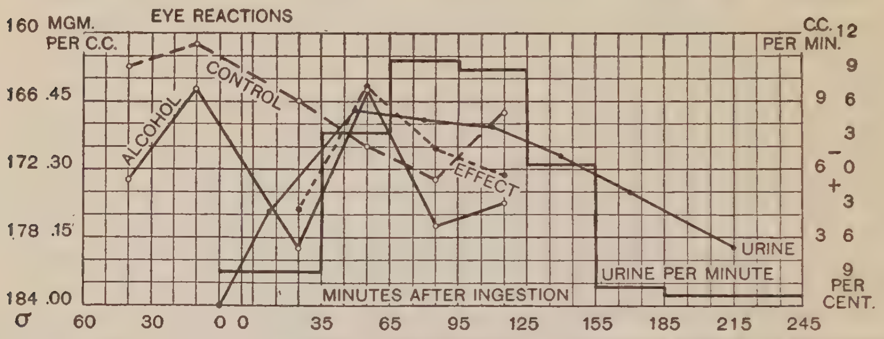

FIG. 21.—Effect of Alcohol on Speed of Eye Reaction to Peripheral Stimuli at 30-minute Intervals Following Ingestion Compared with Alcohol Concentration in Urine. (Grape-juice-alcohol Series, 1920, Subject *Mow.*)

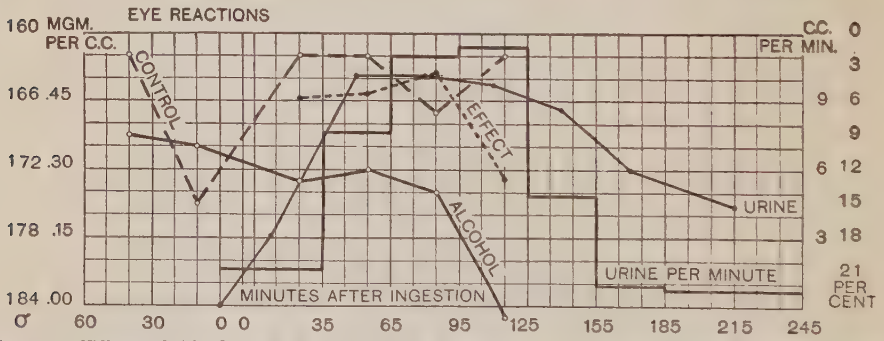

FIG. 22.—Effect of Alcohol on Speed of Eye Reaction to Peripheral Stimuli at 30-minute Intervals Following Ingestion Compared with Alcohol Concentration in Urine. (Cider-alcohol Series, 1920, Subject *Mow.*)

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, pp. 77 and 250.

alcohol, 1920) has 2 periods when the reaction time is longer after alcohol. Probably the minus results for periods 4 and 5 are due to the different levels for the preliminary values in the alcohol and control experiments in this series. The average alcohol effect for all five series is a slowing in the reaction time of 4.2 per cent. This is only a little less than the average effect of alcohol found with the pursuit-pendulum measurement which, from some points of view, was also a reaction test. The influence of alcohol in lengthening the reaction time of the eye to peripheral stimuli is in line with the alcohol effect on our other tests. The seeming contradictions which Dodge and Benedict[a] found between their eye-reaction data and other measures were quite certainly due to rapid changes in their reaction-time scores on account of pronounced learning by the subjects.

Sensory Thresholds.

Each of the five series of measurements on *Mow* made use of one sensory-threshold test. In the water-alcohol series, the measurement was of visual acuity, but in the four following groups of experiments the sensitivity to electric shock was used. The technique for these threshold measurements is described on pages 14 and 15.

Visual Acuity.

The results for the visual acuity of *Mow* are given in degree-seconds on the arc of vision in table 49. The usual standard visual acuity of $\frac{20}{20}$ signifies that the subject distinguishes the direction of line when the stroke width corresponds to 60 degree-seconds on his arc of vision. The normal visual acuity of *Mow,* as found in the water-alcohol series and with the Ives-Cobb apparatus, was about one-half this amount. The average value for the preliminary determinations is 31.5 degree-seconds. Following the control solution, the visual acuity is poorer by a small amount, while the average readings after alcohol are, in general, smaller than the corresponding values after the control dose. The effect of alcohol on the visual acuity is therefore +0.9, −3.2, and −3.2 per cent for periods 3, 4, and 5, respectively, with an average of −1.8 per cent. It was necessary to take threshold readings for visual acuity in different axes to keep the subject in ignorance of the direction in which to expect lines. The measurement required a larger proportion of time in the period than seemed wise to devote to it, and hence in the succeeding three series the electrical threshold was substituted.

Sensitivity to Electric Shock.

The results in terms of volts[b] for the electrical-threshold measurements in the beer-alcohol and grape-juice-alcohol 1919 series are also given in table 49, and those for the grape-juice-alcohol series of 1920 and the cider-alcohol series in figures 23 and 24, respectively. The general results in all four series for the electrical threshold are much like those found for visual acuity in the water-alcohol series in that the alcohol effect is uncertain in direction, but in terms of averages for the 2-hour interval following alcohol tends to appear as a minus value, that is, an improved or lowered threshold. As appears in the effect curve given in figure 23 for the grape-juice series of 1920, the values for periods 3, 5, and 6 are plus. The average alcohol effect for the four periods after the dose is +2.6 per cent.

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 90.

[b] See description of method, p. 14.

TABLE 49.—*Effect of dilute alcohol on sensory thresholds.*

Series, type, and date of experiments.	Sensitivity at successive half-hours.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
VISUAL ACUITY.							
Water-alcohol series, 1919:	*deg. sec.*	*deg. sec.*	*deg. sec.*	*deg. sec.*	*deg. sec.*	*deg. sec.*	*deg. sec.*
Control: Nov. 5	35.2	35.5	36.1	35.6	33.5	....	35.1
Nov. 8	30.9	31.1	32.9	33.6	34.4	....	33.6
Nov. 19	30.4	30.6	29.7	30.3	29.3	....	29.8
Nov. 21	29.1	31.1	30.6	31.4	31.1	....	31.0
Nov. 22	29.8	30.5	31.0	31.0	32.0	....	31.3
Averages	**31.1**	**31.8**	**32.1**	**32.4**	**32.1**	....	**32.2**
Differences	(31.4)		+0.7	+1.0	+0.7	....	+0.8
Alcohol: Nov. 6	33.2	34.7	35.6	33.3	33.5	....	34.1
Nov. 7	32.1	31.6	32.1	32.0	32.0	....	32.0
Nov. 10	34.0	34.4	33.7	32.0	31.8	....	32.5
Nov. 17	30.4	29.8	31.0	31.4	29.9	....	30.8
Nov. 18	29.1	28.2	30.9	29.6	29.6	....	30.0
Averages	**31.8**	**31.7**	**32.7**	**31.7**	**31.4**	....	**31.9**
Differences	(31.7)		+1.0	±0.0	−0.3	....	+0.2
Effect in differences	....	....	+0.3	−1.0	−1.0	....	−0.6
Effect in per cent	(31.5)		+0.9	−3.2	−3.2	....	−1.8
ELECTRICAL THRESHOLD.							
Beer-alcohol series, 1919:	*volts*	*volts*	*volts*	*volts*	*volts*	*volts*	*volts*
Control: Dec. 4	71	77	74	82	79	84	80
Dec. 5	84	75	80	81	78	84	81
Dec. 10	76	73	74	67	78	79	75
Dec. 11	79	78	78	81	79	80	80
Averages	**77.5**	**75.8**	**76.5**	**77.8**	**78.5**	**81.8**	**78.7**
Differences	(76.7)		−0.2	+1.1	+1.8	+5.1	+2.0
Alcohol: Dec. 3	75	78	75	86	86	82	82
Dec. 8	84	90	88	88	84	86	87
Dec. 9	79	76	74	80	79	81	79
Dec. 13	80	84	80	81	76	76	78
Averages	**79.5**	**82.0**	**79.3**	**83.8**	**81.3**	**81.3**	**81.4**
Differences	(80.8)		−1.5	+3.0	+0.5	+0.5	+0.6
Effect in differences	....	....	−1.3	+1.9	−1.3	−4.6	−1.3
Effect in per cent	(78.8)		−1.6	+2.4	−1.6	−5.8	−1.7
Grape-juice-alcohol series, 1919:							
Control: Dec. 2	67	65	78	75	75	76	76
Dec. 16	82	79	78	77	73	75	76
Dec. 20	66	67	68	65	66	67	67
Averages	**71.7**	**70.3**	**74.7**	**72.3**	**71.3**	**72.7**	**72.8**
Differences	(71.0)		+3.7	+1.3	+0.3	+1.7	+1.8
Alcohol: Dec. 1	77	81	80	82	84	83	82
Dec. 15	80	83	82	83	82	86	83
Dec. 17	77	75	72	71	72	74	72
Dec. 18	63	74	80	66	70	74	73
Averages	**74.3**	**78.3**	**78.5**	**75.5**	**77.0**	**79.3**	**77.6**
Differences	(76.3)		+2.2	−0.8	+0.7	+3.0	+1.3
Effect in differences	....	....	−1.5	−2.1	+0.4	+1.3	−0.5
Effect in per cent	(73.7)		−2.0	−2.8	+0.5	+1.8	−0.6

However, the extraordinary variation between the level of the averages for control and for alcohol performance, as seen in figure 23, is such that no confidence may be placed in the contrasting levels following dosage. The cider-alcohol set (see fig. 24) gives the clearest indication of any of the five series that the alcohol effect is in the direction of a lower or improved threshold; and four of the five series really point in this direction with the sensory-threshold measurements which we have employed. Since these are the only psychological data which we have in which the alcohol effect appears to be opposed to the usual direction, these results have been carefully scrutinized. They apparently confirm some observations of Lange and Specht,[a] who concluded that the sensory threshold for hearing was lowered after alcohol.

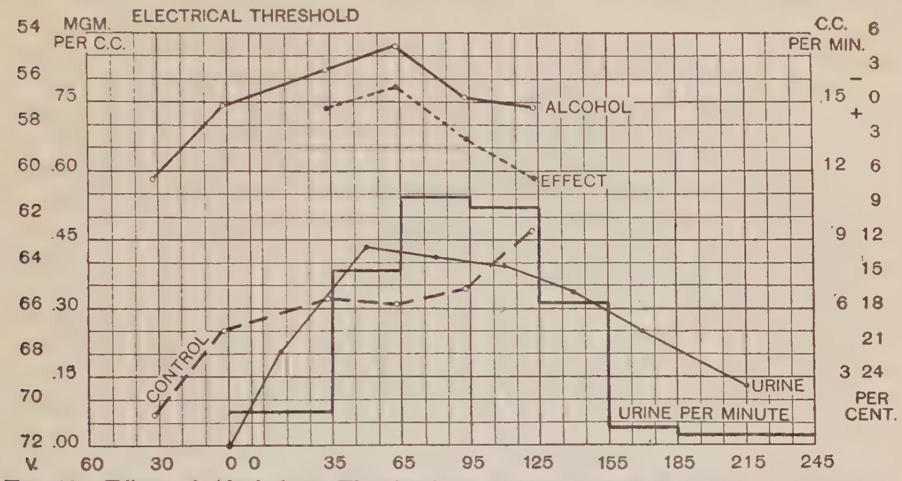

FIG. 23.—Effect of Alcohol on Threshold for Electric Shock Measured at 30-minute Intervals Following Ingestion Compared with Alcohol Concentration in Urine. (Grape-juice-alcohol Series, 1920, Subject *Mow.*)

This chart exhibits the striking peculiarity of great difference between the alcohol and control levels of measurement.

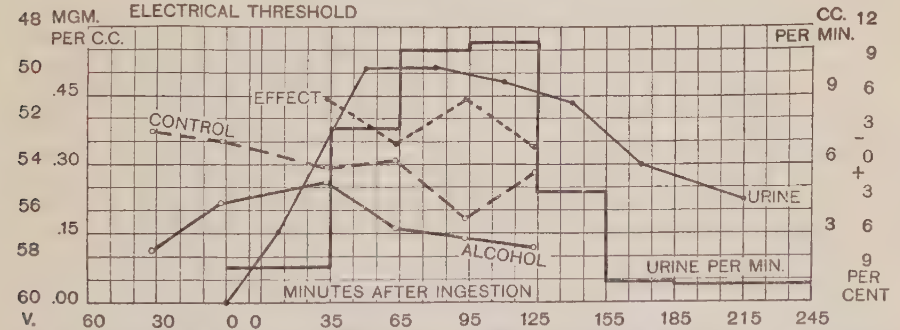

FIG. 24.—Effect of Alcohol on Threshold for Electric Shock Measured at 30-minute Intervals Following Ingestion Compared with Alcohol Concentration in Urine. (Cider-alcohol Series, 1920, Subject *Mow.*)

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[a] Lange and Specht, Zeitschr. f. Pathopsychologie, 1915, 3, p. 155.

We are not in position to discuss the mechanism by which the alcohol produces its change in any of our measurements. The present research concerns itself with the more preliminary problem of whether or not there is a change following alcohol taken in a moderate amount and in dilute solution and what the direction of this change appears characteristically to be. We must limit ourselves to the data which are at hand. From these it seems, although the evidence is by no means so clear and convincing as in most of our measurements, that the typical effect on the sensory threshold with this subject is to lower or improve it. We are bound to note that threshold observations require the subject to neglect distracting and disturbing stimuli and attend to the particular sensation which he is supposed to report when it becomes of sufficient intensity to be recognized. It seems to the writer quite possible that in such a case alcohol may assist in overcoming or minimizing distraction. This would narrow the field of attention and thus, on the average, lower the threshold observation. It is a matter of much regret that the thresholds taken in each period are not sufficient in number for a trustworthy statement to be made as to the percentage variability which would supply another means of measuring the alcohol effect on the sensory threshold. Our results for the sensory-electric threshold do not agree with the average finding of Dodge and Benedict,[a] who used the electrical threshold obtained by faradic stimulation. We have no satisfactory explanation of the discrepancy, which is all the more difficult to understand, because their positive results of a heightened threshold after alcohol are much larger than our negative results.

JOHNSON'S SUBSTITUTION CODE TEST.

The Johnson code test, which was used as a measure of efficiency in this series of tests with *Mow*, has been described on page 26. The results in the first three alcohol series are given in table 50. In the water-alcohol series subject *Mow* found it possible in the preliminary period to transliterate an average of about 27 letters per minute. In the second and third experimental series his ability progressively improved, increasing in the beer-alcohol series to an average preliminary normal performance of 33.3 letters per minute, and in the grape-juice-alcohol series of 1919 to 34.5 letters per minute. There was a tendency to a slight improvement throughout the experimental session, indicated by the fact that the differences following the control dose are slightly plus, notwithstanding that some fatigue must have gradually developed. Following the alcohol dose, they are always minus for the three series reported in this table.

The alcohol effect in the first series shows its maximum of decrease in period 4 amounting to 8.8 per cent and a decrease in period 5 of 5.5 per cent, the average for the 3 periods in the water-alcohol series being a decrease in efficiency of 5.4 per cent. In the beer-alcohol series the maximum appears in the fifth period, with a decrease in efficiency of 13.5 per cent. The average for the 4 periods was 8.0 per cent. The grape-juice-alcohol series of 1919 give equally large decrements in periods 3 and 5, both of which are practically 11 per cent, while the result for the intervening period 4 is −9.0 per cent. The average for the 4 periods is a decreased efficiency of 9.4 per cent. In the grape-juice-alcohol series of 1920 (see table 69, p. 255) the averages were −7.3, −8.9, −9.2, and +2.9 per cent for the 4 periods in order, with an average decrement of 5.6 per cent.

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 145.

TABLE 50.—*Effect of dilute alcohol on performance of a substitution code test.*

Series, type, and date of experiments.	Letters per minute at successive half-hours.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Water-alcohol series, 1919:							
Control: Nov. 5	20.7	22.9	21.7	22.1	20.0	....	21.3
Nov. 8	26.5	27.5	20.1	27.0	28.0	....	25.0
Nov. 19	28.5	29.7	30.0	29.4	28.8	....	29.4
Nov. 21	26.3	29.4	30.6	28.8	28.8	....	29.4
Nov. 22	30.9	31.9	29.1	30.3	32.3	....	30.6
Averages	**26.6**	**28.3**	**26.3**	**27.5**	**27.6**	....	**27.1**
Differences	(27.5)		− 1.2	±0.0	+ 0.1	....	−0.4
Alcohol: Nov. 6	23.8	24.6	22.2	23.4	22.1	....	22.6
Nov. 7	26.1	25.6	24.6	24.4	23.6	....	24.2
Nov. 10	27.3	24.8	25.9	23.1	27.0	....	25.3
Nov. 17	26.5	30.9	26.2	25.9	28.8	....	27.0
Nov. 18	29.7	30.6	27.5	26.3	26.3	....	26.7
Averages	**26.7**	**27.3**	**25.3**	**24.6**	**25.6**	....	**25.2**
Differences	(27.0)		− 1.7	−2.4	− 1.4	....	−1.8
Effect in differences	......	......	− 0.5	−2.4	− 1.5	....	−1.5
Effect in per cent	(27.3)		− 1.8	−8.8	− 5.5	....	−5.4
Beer-alcohol series, 1919:							
Control: Dec. 4	32.3	32.9	31.6	32.3	31.2	31.9	31.8
Dec. 5	34.9	33.0	33.7	33.0	32.0	33.3	33.0
Dec. 10	33.7	33.7	30.9	33.7	33.7	33.0	32.8
Dec. 11	32.6	31.6	34.9	33.7	37.5	34.1	35.1
Averages	**33.4**	**32.8**	**32.8**	**33.2**	**33.6**	**33.1**	**33.2**
Differences	(33.1)		− 0.3	+0.1	+ 0.5	±0.0	+0.1
Alcohol: Dec. 3	32.3	34.1	30.3	31.6	28.8	31.6	30.6
Dec. 8	34.1	33.3	33.7	29.4	26.5	31.2	30.2
Dec. 9	33.7	33.3	29.4	31.9	30.9	30.3	30.6
Dec. 13	34.5	32.6	30.3	33.3	31.6	33.7	32.2
Averages	**33.6**	**33.3**	**30.9**	**31.6**	**29.5**	**31.7**	**30.9**
Differences	(33.5)		− 2.6	−1.9	− 4.0	−1.8	−2.6
Effect in differences	......	......	− 2.3	−2.0	− 4.5	−1.8	−2.7
Effect in per cent	(33.3)		− 6.9	−6.0	−13.5	−5.4	−8.0
Grape-juice-alcohol series, 1919:							
Control: Dec. 2	32.6	31.9	32.3	30.6	32.6	30.6	31.5
Dec. 16	34.9	35.7	35.7	34.5	35.7	35.0	35.2
Dec. 20	34.9	33.4	34.5	37.5	35.7	34.1	35.5
Averages	**34.1**	**33.6**	**34.2**	**34.2**	**34.7**	**33.2**	**34.1**
Differences	(33.8)		+ 0.4	+0.4	+ 0.9	−0.6	+0.3
Alcohol: Dec. 1	30.6	32.2	28.8	29.4	30.0	29.7	29.5
Dec. 15	34.1	36.1	31.3	31.9	31.3	29.7	31.1
Dec. 17	36.1	38.5	34.1	34.9	32.3	33.7	33.8
Dec. 18	37.5	36.8	33.0	33.8	36.1	36.1	34.8
Averages	**34.6**	**35.9**	**31.8**	**32.5**	**32.4**	**32.3**	**32.3**
Differences	(35.2)		− 3.4	−2.7	− 2.8	−2.9	−3.0
Effect in differences	......	......	− 3.8	−3.1	− 3.7	−2.3	−3.2
Effect in per cent	(34.5)		−11.0	−9.0	−10.7	−6.7	−9.4

The results for the code test when the alcohol was diluted with cider are given in graphic form in figure 25. The preliminary values for the alcohol and control days deviate widely, and the curves cross each other. Little change is apparent in the averages following the control dose, but after the alcohol the number of letters transliterated per minute falls off sharply, so that the alcohol values are considerably below those for the control series. The maximum, −11.3 per cent, is in period 4 and corresponds closely with the appearance of maximum concentration of alcohol in the urine. All the periods for this series show percentage effects in the direction of decreased efficiency, the average for the series being −7.3 per cent.

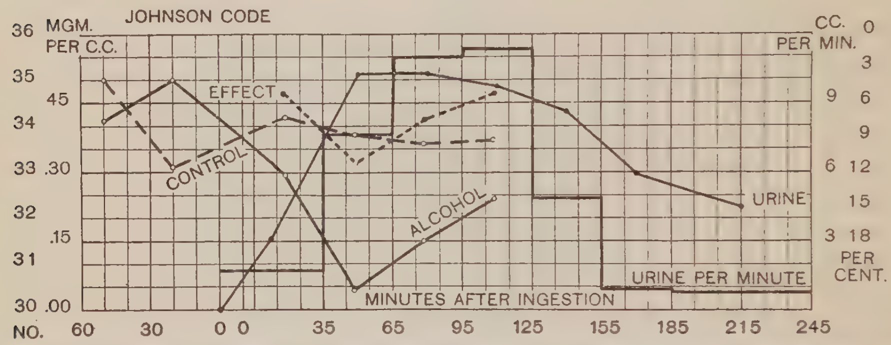

FIG. 25.—Effect of Alcohol on Speed and Accuracy of Transliterating Code Material at 30-minute Intervals After Ingestion Compared with Alcohol Concentration in Urine. (Cider-alcohol Series, 1920, Subject *Mow*.)

Of the 19 experimental periods following alcohol which are represented by these five series with *Mow*, there is only 1 period (period 6 in series 4) which shows a plus value. The characteristic effect for the 27.5 grams of alcohol taken in 1 liter of solution is thus to produce a decrease in the subject's ability to transliterate letters. This decrease in efficiency tends to be most strongly marked in periods 4 and 5, corresponding to the early intervals when the alcohol has reached its highest concentration in the urine. The decrease amounts in these periods to about 9 per cent. The average for the 2 hours following the ingestion of alcohol is a decrease in ability of 7.1 per cent. Errors were not sufficiently numerous to be tabulated for the study of any alcohol effect upon their incidence. The code test was employed in the later experiments on *Mow* with 15-minute periods (see page 182) and in the series with the group of subjects described in Chapter VI, where further data are to be found.

SUMMARY OF RESULTS OF PSYCHOLOGICAL MEASUREMENTS IN 30-MINUTE PERIODS WITH DILUTE ALCOHOL.

A review of the results of these five series of experiments on *Mow*, in which 30-minute periods were used and the alcohol was diluted with various substances, is provided in table 51.[a] For each measurement used in

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[a] For notes on the subjective effects experienced in these experiments with dilute alcohol, see the Appendix, page 284.

TABLE 51.—*Summary for the percentage effect of dilute alcohol on various measurements used in five series of experiments on Mow, with statement of relative prominence of the average effects in the different series.*

Measurement.	Periods after dose.	Comparative alcohol effect in five series of experiments.										Average for five series.
		Water-alcohol, 1919.		Beer-alcohol, 1919.		Grape-juice-alcohol, 1919.		Grape-juice-alcohol, 1920.		Cider-alcohol, 1920.		
		Per cent.	Rank.	Per cent.	Rank.	Per cent.	Rank.	Per cent.	Rank.	Per cent.	Rank.	
Station........	3	+32.0	3	+45.8	5	+35.0	4	− 4.5	1	+29.1	2	+27.5
	4	+25.0	2	+53.2	5	+35.6	3	+23.3	1	+44.9	4	+36.4
	5	+33.2	5	+25.1	3	+ 7.6	1	+11.9	2	+27.0	4	+21.0
	6	....	...	+10.0	2	+12.8	4	− 2.4	1	+10.8	3	+ 7.8
Average...	.....	+30.1	4	+33.5	5	+22.8	2	+ 7.1	1	+28.0	3	+24.3
Finger movements.	3	− 1.7	5	− 0.4	4	+ 1.0	1	+ 0.1	3	+ 0.3	2	− 0.1
	4	− 4.1	5	− 2.6	4	− 1.7	3	− 1.3	2	− 0.3	1	− 2.0
	5	− 2.6	3	− 3.8	4	− 1.9	1	− 4.8	5	− 2.4	2	− 3.1
	6	....	...	− 3.2	4	− 2.3	3	± 0.0	1	− 0.8	2	− 1.6
Average...	.....	− 2.8	5	− 2.5	4	− 1.2	2	− 1.5	3	− 0.8	1	− 1.8
Pursuit pendulum.	3	− 4.5	5	− 2.1	2	− 2.1	2	+ 1.8	1	− 2.9	4	− 2.0
	4	− 6.5	3	− 2.6	1	− 5.2	2	−10.0	4	−10.0	4	− 6.9
	5	− 6.7	3	− 2.1	1	− 5.6	2	− 8.6	4	−10.9	5	− 6.8
	6	....	...	− 3.7	3	− 3.3	2	+ 1.3	1	− 6.6	4	− 3.1
Average...	.....	− 5.9	4	− 2.6	1	− 4.1	3	− 3.9	2	− 7.6	5	− 4.8
Pursuit pendulum: Coefficient of variability.	3	+73.1	5	+59.0	4	+35.3	3	−17.7	1	+ 4.1	2	+30.8
	4	+90.4	5	+ 5.1	1	+71.5	4	+32.6	2	+37.4	3	+47.4
	5	+80.8	5	+10.2	1	+25.8	3	+14.2	2	+38.6	4	+33.9
	6	....	...	+35.9	3	+38.8	4	− 3.5	1	+18.4	2	+22.4
Average...	.....	+81.4	5	+27.6	3	+42.9	4	+ 6.4	1	+24.6	2	+36.6
Pursuitmeter...	3	+ 9.3	2	+ 9.5	3	+ 7.0	1	+16.4	4	+ 9.5	3	+10.3
	4	+13.9	1	+27.2	5	+23.8	4	+22.4	3	+21.6	2	+21.8
	5	+12.6	1	+25.7	4	+19.1	2	+23.7	3	+26.4	5	+21.5
	6	....	...	+26.6	4	+15.2	2	+13.8	1	+16.2	3	+18.0
Average...	.....	+11.9	1	+22.3	5	+16.3	2	+19.1	4	+18.4	3	+17.6
Eye movements, left.	3	+ 3.3	1	+ 7.6	5	+ 5.4	2	+ 6.3	4	+ 6.1	3	+ 5.7
	4	+ 5.4	1	+ 8.7	4	+ 6.5	2	+10.4	5	+ 7.1	3	+ 7.6
	5	+ 9.8	4	+ 7.6	3	+ 4.3	1	+ 5.2	2	+10.2	5	+ 7.4
	6	....	...	+ 7.6	4	+ 4.3	2	+ 5.2	3	+ 4.1	1	+ 5.3
Average...	.....	+ 6.2	2	+ 7.9	5	+ 5.1	1	+ 6.8	3	+ 6.9	4	+ 6.6
Eye movements, right.	3	+ 3.5	1	+ 5.8	4	+ 5.7	3	+ 9.0	5	+ 4.6	2	+ 5.7
	4	+ 2.3	1	+ 4.6	2	+ 6.9	4	+ 6.7	3	+ 8.1	5	+ 5.7
	5	+ 8.2	4	+ 5.8	2	+ 6.9	3	+ 4.5	1	+ 9.2	5	+ 6.9
	6	....	...	+ 3.5	2	+ 5.7	4	+ 3.4	1	+ 4.6	3	+ 4.3
Average...	.....	+ 4.7	1	+ 4.9	2	+ 6.3	4	+ 5.9	3	+ 6.6	5	+ 5.7

TABLE 51.—*Summary for the percentage effect of dilute alcohol on various measurements used in five series of experiments on Mow, with statement of relative prominence of the average effects in the different series*—Continued.

Measurement.	Periods after dose.	Comparative alcohol effect in five series of experiments.										Average for five series.
		Water-alcohol, 1919.		Beer-alcohol, 1919.		Grape-juice-alcohol, 1919.		Grape-juice-alcohol, 1920.		Cider-alcohol, 1920.		
		Per cent.	Rank.	Per cent.	Rank.	Per cent.	Rank.	Per cent.	Rank.	Per cent.	Rank.	
Eye reactions..	3	+ 1.8	1	+11.8	5	+ 6.2	4	+ 3.6	2	+ 5.9	3	+ 5.9
	4	+ 0.6	2	+ 6.6	4	+ 9.0	5	− 7.2	1	+ 5.3	3	+ 2.9
	5	+ 2.4	2	+ 5.9	4	+ 6.9	5	− 1.8	1	+ 3.5	3	+ 3.4
	6	....	...	+ 8.6	3	+ 0.7	2	+ 0.6	1	+12.9	4	+ 5.7
Average...	.....	+ 1.6	2	+ 8.2	5	+ 5.7	3	− 1.2	1	+ 6.9	4	+ 4.2
Code..........	3	− 1.8	1	− 6.9	3	−11.0	5	− 7.3	4	− 5.2	2	− 6.4
	4	− 8.8	2	− 6.0	1	− 9.0	4	− 8.9	3	−11.3	5	− 8.8
	5	− 5.5	1	−13.5	5	−10.7	4	− 9.2	3	− 7.6	2	− 9.3
	6	....	...	− 5.4	3	− 6.7	4	+ 2.9	1	− 5.2	2	− 3.6
Average...	.....	− 5.4	1	− 8.0	4	− 9.4	5	− 5.6	2	− 7.3	3	− 7.1
Sensory thresholds[1].....	3	[2]+ 0.9	1	[3]− 1.6	3	[3]− 2.0	4	[3]+ 0.6	2	[3]− 6.2	5	− 1.7
	4	− 3.2	5	+ 2.4	1	− 2.8	4	− 1.2	2	− 1.8	3	− 1.3
	5	− 3.2	4	− 1.6	3	+ 0.5	2	+ 3.1	1	− 5.8	5	− 1.4
	6	....	...	− 5.8	4	+ 1.8	2	+ 7.7	1	− 1.5	3	+ 0.6
Average...	.....	− 1.8	4	− 1.7	3	− 0.6	2	+ 2.6	1	− 3.8	5	− 1.1
Total of average ranks.	.....	....	29	....	37	....	28	....	21	....	35	....
Rank by total..	.....	....	3	....	5	....	2	....	1	....	4	....

[1] The characteristic alcohol effect is taken to be lowering of the threshold, therefore the largest percentage of lowering is ranked 5 and the least 1.

[2] Visual acuity threshold.

[3] Threshold of finger-tips for electric shock.

testing this man the alcohol effect is given for every experimental period following the dose in the five series of experiments, water-alcohol, beer-alcohol, grape-juice-alcohol of 1919, grape-juice-alcohol of 1920, and cider-alcohol of 1920. At the right side of the table both the period and the general averages are given for all five series of experiments. Each value shown in this column is obtained from the horizontal line of figures at its left. The data for station area and for variation in amplitude of finger movement are not included in this table, as they are considered supplementary to the discussions of the effect of alcohol on these two measurements.

These percentage results need not be reviewed in detail. The effect of alcohol is most prominent in the station and pursuitmeter tests, as well as in the variability of the performance with the pursuit pendulum. For these three measures the average effects are, in order, 24.3, 17.6, and 36.6 per cent, respectively. The effect on the two eye movements and on the code test were next in order, with changes of 6.6, 5.7, and 7.1 per cent, respectively. The alcohol effect on the pursuit-pendulum performance was a reduced efficiency in coordination of −4.8 per cent and on the eye-reaction time a slower speed by +4.2 per cent. The speed of finger movement demonstrates the least average alcohol effect in the direction of decreased efficiency, being −1.8 per cent. We have seen, however, that the variations in the amplitude of the finger movement, which perhaps in this case can not be considered a measurement of efficiency, were large, being on the average about as great as the variability in the pursuit-pendulum performance after alcohol. The only measurement that showed any increase in ability, or what might be termed efficiency, following the alcohol was the sensory threshold, which involved visual acuity in the first series and sensitivity to electrical shock in the four other series. Of the 19 periods after alcohol, 7 give plus results (heightened threshold) and 12 are minus, a greater apparent sensitivity, with a general average for all series of −1.1 per cent. In nearly all the measurements there are one or two exceptions to the general direction in the 19 periods. In the case of the pursuitmeter results and of both eye movements, however, all of the 19 periods in each case are plus in direction. The sensory threshold is the only measurement in which the plus and minus signs were so nearly of equal number. While the average alcohol effect represents a slight improvement in the threshold, it must be admitted that the effect is, in this case, the least in order of magnitude and, due to the fluctuating sign, the least convincing of any of the 10 measurements shown in the summary table.

Each period average value in table 51 has been ranked in order from 1 to 5, according to the amount of the alcohol effect, 1 indicating the smallest and 5 the largest effect. Thus, in the first horizontal line of the table, representing station in period 3, the series which shows the smallest effect is the grape-juice-alcohol series of 1920, with a percentage of −4.5. The next largest for this measurement and period is the cider-alcohol series (+29.1 per cent), which is ranked 2. The third is the water-alcohol series (+32.0 per cent), and the fourth the grape-juice-alcohol series of 1919, with a percentage effect of +35.0. The strongest effect was found in the beer-alcohol series, with a percentage of +45.8. Each period for every measurement has been ranked in a similar way. From the totals of the four ranks in each series, the general rank for each of the five series has been determined for each measurement. Since in the water-alcohol series there were but 3 periods after alcohol, the total of the three ranks was increased by one-third to make it comparable with those for the other experimental series. For the station test as illustrated, the various series take the following rank from least to strongest effect: grape juice, 1920; grape juice, 1919; cider; water; and finally the strongest effect is found in the beer-alcohol series with this measurement. Having given such ranks for relative prominence of the alcohol effect in each measurement, these measurement ranks were totaled for each of the five series, as shown at the bottom of table 51, and on the basis of these totals the five series were given a total rank. Obviously, the series with the smallest total of ranks has, as a general rule, shown the smallest alcohol effect. The various series in chronological order are given in the table from left to right, and are seen to give total ranks for alcohol effect of 3, 5, 2, 1, and 4.[a]

From these five series of 30-minute experiments on one subject, we may therefore conclude:

1. An amount of alcohol, 27.5 grams, taken in a total volume of 1 liter on a relatively empty stomach and consumed within 10 minutes, produces clearly measurable decrements in the motor efficiency of a man during a 2-hour interval following ingestion.

2. Irrespective of whether the alcohol is diluted with water, beer, grape juice, or cider, the results are in the same direction. Taken with the various dilutants, the alcohol effect is roughly of the same order of magnitude, but actually larger when beer and cider are ingested.

3. In repeated series of experiments on the same individual, the alcohol effect does not regularly decrease in successive series of measurements. Such tolerance as may be developed in and through the experimentation does not suffice to abolish the measurable effect of the alcohol.

4. The effect of alcohol in terms of per cent is not of equal size in all the measurements, but in general is from 2 to 30 per cent. It is characteristically in the direction of poorer efficiency in the various measurements. The effect tends to be most pronounced in coordinations which require the continuous action or activity of the subject being tested.

5. In only one instance, sensory threshold, of the various tests employed have we discovered anything in the nature of an alcohol effect which is in the direction of an improved performance. But here the average effect is quite small and the signs indicating the direction of influence are about half plus and half minus, so the results are not so conclusive as our other findings.

6. The influence of alcohol on the various measurements tends to reach its maximum 60 to 90 minutes after the completed ingestion of the dose. These preliminary data with *Mow* indicate that the intensity of the effect bears a close relationship to the appearance of the maximum concentration of alcohol in the urine. Of two series for which there are comparable data, the one which shows the highest maximal concentration of alcohol in the urine also shows the more marked general alcohol effect in terms of per cent. Fuller discussion of this relationship is reserved for Chapter VII, but the accumulating evidence from each series of experiments is briefly summarized.

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[a] In ranking the effect on the sensory threshold, a lower threshold was assumed as the characteristic alcohol effect and the ranks were assigned accordingly. Of the five alcohol series, only the last two, those in 1920, can be compared on the basis of their average maximum concentration of alcohol in the urine. A reinspection of figures 23 and 24, for example, will show the relation of these two series in this regard. The fourth series, that with grape juice and alcohol, 1920, shows a maximum in the curve of 0.43 mg. per cubic centimeter of urine, from which level the alcohol concentration slowly falls. The cider series, which is undoubtedly affected by the fact that two of the doses were somewhat larger than usual, gives a maximal alcohol concentration in the urine of 0.51 mg. per cubic centimeter. This is a definitely higher concentration level than found in series 4. The intensity of the alcohol effect, therefore, in the two instances agrees in direction with the difference of alcohol concentration in the body fluids.

VOLUME OF URINE AFTER INGESTION OF DILUTE ALCOHOL.

In the foregoing discussion of five series of experiments on *Mow*, in which 27.5 grams of ethyl alcohol were given in a total volume of 1,000 c. c. of liquid, the effects of the alcohol upon the results of various psychological measurements have been considered. In addition to these measure-

TABLE 52.—*Effect of dilute alcohol on total volume of urine excreted within 3 hours of ingestion.*

Series, type, and date of experiments.	Volumes of urine at successive half-hours.						During next 1 hour.	Total after dose.
	Preliminary.		Following dose.					
	[1]1	2	3	4	5	6		
Water-alcohol series, 1919:	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.
Control: Nov. 5	....	70	190	340	325	....	305	1,160
Nov. 8	250	50	42	133	275	....	208	658
Nov. 19	60	66	75	255	325	....	188	843
Nov. 21	85	45	32	130	240	....	165	567
Nov. 22	183	44	95	313	302	....	108	818
Averages	144	55	87	234	293	....	195	809
Differences	....	(55)	+32	+179	+238	....	+140	....
Alcohol: Nov. 6	....	52	129	255	323	....	370	1,077
Nov. 7	205	35	34	172	225	....	343	774
Nov. 10	82	40	85	177	350	....	487	1,099
Nov. 17	48	60	95	244	332	....	404	1,075
Nov. 18	100	54	75	300	350	....	212	937
Averages	109	48	84	230	316	....	363	993
Differences	....	(48)	+36	+182	+268	....	+315	....
Effect in differences	....	....	+ 4	+ 3	+ 30	....	+175	....
Effect in per cent[2]	....	....	+ 5	+ 1	+ 10	....	+ 90	....
Beer-alcohol series, 1919:								
Control: Dec. 4	177	52	50	185	342	170	60	807
Dec. 5	155	36	50	200	345	205	113	913
Dec. 10	270	53	52	128	368	340	141	1,029
Dec. 11	140	95	105	232	365	330	194	1,226
Averages	185	59	64	186	355	261	127	993
Differences	....	(59)	+ 5	+127	+296	+202	+ 68	....
Alcohol: Dec. 3	73	50	105	330	346	256	63	1,100
Dec. 8	60	32	30	75	252	270	170	797
Dec. 9	170	46	48	160	348	360	172	1,088
Dec. 13	172	43	36	110	336	317	120	919
Averages	119	43	55	169	320	301	131	976
Differences	....	(43)	+12	+126	+277	+258	+ 88	....
Effect in differences	....	....	+ 7	− 1	− 19	+ 56	+ 20	....
Effect in per cent[2]	....	....	+11	− 1	− 5	+ 21	+ 16	....
Grape-juice-alcohol series, 1919:								
Control: Dec. 2	137	31	35	213	300	202	92	842
Dec. 16	125	65	32	128	240	90	133	623
Dec. 20	242	84	66	242	325	165	94	892
Averages	168	60	44	194	288	152	106	784
Differences	....	(60)	−16	+134	+228	+ 92	+ 46	....
Alcohol: Dec. 1	155	55	70	260	375	320	200	1,225
Dec. 15	425	136	188	273	298	299	375	1,433
Dec. 17	184	43	67	196	312	157	140	872
Dec. 18	97	60	60	183	387	265	162	1,057
Averages	215	73	96	228	343	260	219	1,146
Differences	....	(73)	+23	+155	+270	+187	+146	....
Effect in differences	....	....	+39	+ 11	+ 42	+ 95	+100	....
Effect in per cent[2]	....	....	+89	+ 6	+ 18	+ 62	+ 94	....

For explanation of reference marks, see footnotes on following page.

TABLE 52.—*Effect of dilute alcohol on total volume of urine excreted within 3 hours of ingestion*—Continued.

Series, type, and date of experiments.	Volumes of urine at successive half-hours.						During next 1 hour.	Total after dose.
	Preliminary.		Following dose.					
	[3]1	2	3	4	5	6		
Grape-juice-alcohol series, 1920:	*c. c.*	*c. c.*	*c. c.*	*c. c.*	*c. c.*	*c. c.*	*c. c.*	*c. c.*
Control: Dec. 8		38	28	175	358	273	74	908
Dec. 11		31	31	187	327	287	76	908
Averages		**35**	**30**	**181**	**343**	**280**	**75**	**908**
Differences		(35)	− 5	+146	+308	+245	+ 40	
Alcohol: Dec. 9		35	33	182	305	290	208	1,018
Dec. 10		63	100	283	334	330	207	1,254
Averages		**49**	**67**	**233**	**320**	**310**	**208**	**1,138**
Differences		(49)	+18	+184	+271	+261	+159	
Effect in differences			+23	+ 38	− 37	+ 16	+119	
Effect in per cent[2]			+77	+ 21	− 11	+ 6	+159	
Cider-alcohol series, 1920:								
Control: Dec. 15		42	34	92	240	218	83	667
Dec. 18		51	56	215	325	316	130	1,042
Dec. 22		44	72	242	350	225	49	938
Averages		**46**	**54**	**183**	**305**	**253**	**87**	**882**
Differences		(46)	+ 8	+137	+259	+207	+ 41	
Alcohol: Dec. 13		49	106	277	318	320	140	1,161
Dec. 16		40	64	270	372	317	120	1,143
Dec. 17		43	39	152	293	322	139	945
Dec. 20		51	54	232	325	378	287	1,276
Averages		**46**	**66**	**233**	**327**	**334**	**172**	**1,132**
Differences		(46)	+20	+187	+281	+288	+126	
Effect in differences			+12	+ 50	+ 22	+ 81	+ 85	
Effect in per cent[2]			+22	+ 27	+ 7	+ 24	+ 98	

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[1] Taken at the very beginning of the first preliminary period; the time interval represented is not uniform. The other urine samples were taken at the end of their respective periods. The secretion time represented by the samples passed at the end of period 3 was about 45 minutes.

[2] The percentage alcohol effect is based on the control averages for the respective periods in place of using the average for preliminary periods.

[3] The bladder was emptied at the beginning of preliminary period 1, but the sample was not saved or measured.

ments, two series of supplementary observations were made upon the volume of urine and upon the metabolism. These should be reported before the observations with 15-minute periods are considered. As described in the early part of this chapter, the subject urinated regularly on completing each 30-minute period following the control dose, as well as at the end of the periods following the alcohol dose. The data regarding the volumes of urine excreted have been gathered together in table 52. Usually the urine was also collected at the end of the second preliminary period on each day.

The volumes given for the first preliminary period in table 52 represent unequal secretion intervals and are only recorded to give a rough idea of the characteristic secretion-level that might apply to the particular day. The urine volume may be treated as any other measurement, except, of course, in this instance, since 1 liter of liquid was ingested between periods 2 and 3, very naturally the urinary output in periods 3, 4, 5, and 6 will tend to be much higher than in preliminary period 2. Consequently it seems illogical to base the percentage alcohol effect on the value shown in the preliminary period. We have therefore used the regular difference method of computing the alcohol effect, except that when the percentage was to be determined, the base taken was the average for the corresponding control periods instead of the average of the preliminary periods.

The urinary volumes are not only recorded for periods 3, 4, 5, and 6 following the ingestion of the dose, but also for an extra hour following period 6 or, in the case of the water-alcohol series of 1919, following period 5. Finally, in the column at the extreme right of the table is given the total volume of urine passed in the 3-hour interval following the ingestion of the dose. It is easily observable from this column of the table that on most alcohol days the volume of urine passed exceeds that commonly passed after the ingestion of the control solution. After the alcohol the urinary volume frequently amounts to 1,000 c. c. or above, whereas when the liter of control solution has been taken it is more usually in the neighborhood of 850 or 900 c. c. There are several notes about urination after the ingestion of alcohol in the Appendix. (See pages 286 to 288.)

In the water-alcohol series, all 3 periods gave small plus effects, with a larger volume in the hour following period 5, in which the increase in output was 90 per cent. In the beer-alcohol series we have the following percentage changes: +11, −1, −5, +21, +16. The two minus values, while not to be discounted, are nevertheless small as compared with the others. In the grape-juice-alcohol series of 1919, the effects are always in the direction of an increased output and range in order +89, +6, +18, +62, and +94 per cent. In the grape-juice series of 1920, the effect of alcohol upon the volume of urine is to increase it in all periods except in 5, in which there is an average decrease of 11 per cent. The change in the hour following period 6 is very large (+159 per cent); next in size is the value in period 3, +77 per cent. Finally, in the cider-alcohol series, all of the percentages represent increases, the largest of 98 per cent appearing in the 1-hour period 3 hours after the ingestion of the alcohol. In this series, also, the effect in period 5 is relatively slight.

All of the urinary data taken together demonstrate that with *Mow* there is a positive diuretic effect of the dilute alcohol in the 3-hour period following its ingestion. The effect of alcohol on the volume of the urinary output is least prominent in periods 4 and 5, that is, 60 to 90 minutes after drinking, and is most prominent in the third hour.

MEASUREMENTS OF METABOLISM AFTER INGESTION OF DILUTE ALCOHOL.

In the three series of experiments in 1919, the final period of the psychological observations was succeeded by 2 shorter periods in which only the metabolism was measured.[a] After this final period, i. e., the fifth period in the water-alcohol series, and the sixth period in the beer and grape-juice series, the subject always urinated and then reclined in a steamer chair. He appreciated the opportunity to rest quietly and was undisturbed for a period of from 15 to 20 minutes. Then, while in the same reclining position, he was connected by the regular mouthpiece and noseclip arrangement with a Benedict portable respiration apparatus of the original type. Very brief mention of this apparatus is given on page 12, with reference to more detailed description in previous publications. After a period for the establishment of normal breathing, the metabolism measurements were begun by the taking of three successive readings at expiration as usual. The pulse-rate was counted by means of a stethoscope during the metabolism measurements.

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[a] While all the conditions were not ideally designed for a typical study of the influence of ethyl alcohol on metabolism, the results are considered to throw light on the topic and are confirmed by considerable unpublished material in the Nutrition Laboratory.

TABLE 53.—*Effect of dilute alcohol on oxygen consumption and pulse-rate 2½ to 3 hours following ingestion.*

Series, type, and date of metabolism experiments.	Dose taken.	Period I.			Period II.		
		Time of start.	Oxygen per min.	Pulse-rate.	Time of start.	Oxygen per min.	Pulse-rate.
Water-alcohol series, 1919:	*p. m.*	*p. m.*	*c. c.*		*p. m.*	*c. c.*	
Control: Nov. 19	1^h45^m	3^h50^m	245	64	4^h10^m	246	69
Nov. 21	2 30	4 30	236	64	4 52	241	64
Nov. 22	1 30	3 28	244	68	3 52	245	70
Average	......	......	**242**	**65**	......	**244**	**68**
Alcohol: Nov. 17	2^h30^m	4^h40^m	247	....	5^h00^m	257	....
Nov. 18	2 30	4 50	257	72	5 10	267	76
Nov. 20	1 38	4 00	260	71	4 20	259	70
Average	......	......	**255**	**72**	......	**261**	**73**
Effect in differences	......	......	+13	+ 7	......	+17	+5
Effect in per cent	......	......	+ 5.4	+10.8	......	+ 7.0	+7.4
Beer-alcohol series, 1919:							
Control: Dec. 4	1^h15^m	3^h48^m	235	70	4^h10^m	248	69
Dec. 5	1 30	3 50	229	64	4 14	244	69
Dec. 10	1 48	4 30	243	63	4 52	244	62
Dec. 11	1 43	4 19	232	64	4 40	230	64
Average	......	......	**235**	**65**	......	**242**	**66**
Alcohol: Dec. 3	1^h51^m	4^h30^m	249	69	4^h52^m	249	67
Dec. 9	1 23	3 46	255	71	4 08	258	72
Dec. 13	1 24	4 27	242	66	4 48	240	67
Average	......	......	**249**	**69**	......	**249**	**69**
Effect in differences	......	......	+14	+ 4	......	+ 7	+3
Effect in per cent	......	......	+ 6.0	+ 6.2	......	+ 2.9	+4.5
Grape-juice-alcohol series, 1919:							
Control: Dec. 2	1^h55^m	4^h15^m	240	63	4^h37^m	242	67
Dec. 16	1 30	4 17	242	64	4 38	247	63
Dec. 20	1 25	4 31	249	66	4 53	274	68
Average	......	......	**244**	**64**	......	**254**	**66**
Alcohol: Dec. 1	2^h22^m	4^h53^m	242	....	5^h15^m	243	70
Dec. 15	1 15	4 12	254	67	4 35	253	68
Dec. 17	1 12	4 00	264	71	4 27	268	74
Dec. 18	1 20	4 30	251	67	4 51	256	67
Average	......	......	**253**	**66**	......	**255**	**70**
Effect in differences	......	......	+ 9	+ 2	......	+ 1	+4
Effect in per cent	......	......	+ 3.7	+ 3.1	......	+ 0.4	+6.1

The data for the oxygen consumption and the available pulse-rates are given in table 53. The different experimental series and the various control and alcohol days on which metabolism measurements and pulse-counts were made are listed, together with the time when the ingestion of the control or alcohol doses was completed and the time when the metabolism measurements began. A comparison of these times will show that the first oxygen measurement followed the ingestion of the dose within 2½ to 3 hours. The metabolism period was about 15 minutes in length and was immediately succeeded by a second period of the same length. The two metabolism periods are indicated at the top of the table and must not be confused with the two preliminary periods of psychological measurements which always preceded the taking of the dose for the day. The oxygen consumption per minute given for each period is as usual the average of three computations.[a] These results, obtained with the same subject and within a period of about 30 days, appear to be comparable with one another.

Following the control solution, the oxygen consumption per minute is usually about 244 c. c., which is the general average for all the control experiments. The average of all results following alcohol is 254 c. c. per minute. It is probably more accurate to observe the contrast within each experimental series. The control average has in each case been deducted from the alcohol average, and the difference has been converted into per cent by using as a base the control average. By this method of computation, the alcohol effect in the first series of experiments is an increase of 5.4 per cent in the oxygen consumption in period 1 and of 7.0 per cent in period 2. In the beer-alcohol series the effect is +6.0 per cent in period 1 and +2.9 per cent in period 2. In the grape-juice-alcohol series the alcohol effect is +3.7 per cent and +0.4 per cent for periods 1 and 2, respectively. Thus in each case where it is possible to compute an alcohol effect from the averages it is in the direction of an increased metabolism following the alcohol.

The data on the pulse-rate per minute in every case substantiate the results obtained for the metabolism, though the percentage increases in pulse-rate are somewhat larger than the increases in oxygen consumption per minute. The average effect of alcohol upon the metabolism, as shown in the three experimental series and two periods of measurement, is +4.2 per cent and a similar average for the change in pulse-rate per minute is +6.4 per cent. Whether one of these results is primary and the other secondary or dependent upon it, or whether both arise more or less independently from the common cause resulting from the ingestion of the alcohol, it is not possible to decide. The results are in agreement with the metabolism figures cited from Dr. Carpenter's data obtained when the alcohol was given by rectal injection. (See p. 121). A very definite alcohol effect in the direction of an increased pulse-rate was likewise found in the repose periods of the typewriting experiments. From such a clear change as was observed in that case, it is only natural to expect, in view of the pulse-metabolism relationship, a somewhat similar increase in the metabolism. Hence there is no conflict in our data, and we in this case reach the important conclusion that alcohol given in so dilute a solution as 2.75 per cent by weight produces at a period 3 hours after ingestion a definite rise in the metabolism and in the pulse-rate. A part of the change in this direction is, of course, due to the ingestion of the alcohol dose whose calorific intake is larger than that of the control dose by the amount of alcohol content. It is our opinion, however, that the increase in metabolism is larger than is to be credited to the simple calorific intake in these experiments with dilute alcohol.

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[a] These three computations of the oxygen consumption are the results of three readings of the respiration apparatus which were made at the start and at the end of each metabolism experiment.

INFLUENCE OF DILUTE ALCOHOL MEASURED IN 15-MINUTE PERIODS UNDER VARYING CONDITIONS OF DOSAGE.

In the experiments described in the preceding pages of this chapter it has been shown that our standard dose of dilute alcohol (27.5 grams taken in 1 liter of fluid) produced a definitely measurable effect within the 2 hours following its ingestion, that these effects were present in repeated experiments, and also when the dose was diluted with different substances.[a] It seems clear from the results already discussed that the intensity of the alcohol effect is related to the height of alcohol concentration obtaining in the body fluids at the time, using the concentration in the urine as an index. It was from this vantage ground that further series of experiments with the trained subject *Mow* were planned. The objective was to supply, if possible, a more careful comparison of the intensity and time relations of the psychological effect with the concentration of alcohol in urine. Aside from this, it was desirable to study the effect for a longer interval following ingestion; also to observe if there were characteristic changes produced by taking a larger quantity of the beverage, and from preceding or succeeding the dosage by the ingestion of other fluids.

CONDITIONS OF EXPERIMENTS.

The several series with 15-minute periods which are to be reported in this connection, all performed on *Mow*, are differentiated from the preceding five series with 30-minute periods by the following four conditions:

1. Fewer psychological measurements were used, so that the duration of the experimental period could be reduced to 15 minutes in place of 30 minutes and still, as before, usually include the collection of urine at the end of the period.
2. The experimental session was prolonged to 4 hours; thus there were sixteen 15-minute periods. The first two were preliminary; following the dose there were fourteen periods during which the alcohol effect could be studied, these latter covering an interval of 3½ hours.
3. One set of control experiments on three days is used for comparison with ten different sets of alcohol experiments. In this way the calculated results from the different series of alcohol experiments are more directly comparable with one another.
4. Varying experimental conditions which conceivably might change the alcohol concentration in the urine were used in the different series.

If reference is made to table 37, page 130, which shows the chronological arrangement for these and the other experiments on *Mow*, it will be noted that the 15-minute experiments, Nos. 43 to 69, inclusive, were made with grape juice and alcohol, usually 27.5 grams of alcohol diluted in 300 c. c.

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[a] For notes on subjective effects, see Appendix, pages 284 to 286.

of grape juice, and this further diluted with water to a total volume of 1,000 c. c. This is the dose that was used in the former series 3 and 4 (grape-juice-alcohol 1919 and grape-juice-alcohol 1920), both with 30-minute periods. When a larger amount than 1 liter of this regular dilute alcohol solution was to be given, a second liter was prepared in the same way, so that the beverage actually taken was of the same dilution and composition in every one of these experiments and may be accurately described as a solution containing 2.75 per cent of alcohol by weight. Grape juice was used for dilution because this combination is not unpleasant to take, and as the experimental days were nearly consecutive, it was necessary to provide some dilutant which would not cause nausea or be particularly difficult to drink. A second and very practical advantage is that the unsweetened bottled grape juice uniformly had a very low alcoholic content that could be disregarded. Under the foregoing conditions, the factors of dilution, substance, and content of the dosage do not appear as difficulties in the comparison between various series.

In all of the eleven experimental series, excepting one when the subject was in a post-absorptive condition, *Mow* ate a hearty breakfast in the morning at 7 to 7.30 o'clock, employed the forenoon in laboratory work of various kinds, and 2 hours before taking the alcohol or control solution ate a light lunch consisting of about 200 calories of carbohydrate, i. e., crackers and fruit conserve. Usually, unless the experimental conditions required it, as later explained, the subject drank no water with his light lunch or during the latter part of the morning. Liquids were taken with the breakfast and with the evening meal. There are no special subjective conditions which appear worthy of report from the standpoint of their probable modifying influence on the results of any particular series.[a]

It will be convenient to designate the eleven series by letter. The varying experimental conditions are explained in the notes accompanying the chronological table, but those which characterize the different series may be summarized here and the identity established by giving the numbers of the experiments used in table 37.

A. Standard conditions, with 15-minute periods, continuing 4 hours, uncomplicated. Nos. 43 and 58.

B. Strictly post-absorptive condition. Morning experiment, 8 a. m. to 12 p. m. Nos. 52 and 54.

C. Divided dose, taken in three equal portions, separated by 30-minute intervals; therefore, 333 c. c. at beginning of periods 3, 5, and 7. Nos. 59 and 61.

D. Additional 500 c. c. dose in ten 50 c. c. portions taken at the beginning of each period from periods 7 to 16, inclusive. No. 63.

E. Additional 900 c. c. dose taken in nine 100 c. c. portions, from periods 8 to 16, inclusive. Nos. 60 and 62.

F. Double dose; 2,000 c. c. taken within 20 minutes. No. 44.

G. Standard alcohol dose preceded by 500 c. c. of water taken 1 hour before. Nos. 47 and 49.

H. Standard alcohol dose preceded by 500 c. c. of whole milk taken 1 hour before. Nos. 48 and 50.

I. Standard alcohol dose followed by 500 c. c. of water 1 hour after. Nos. 45 and 51.

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[a] See notes in reference to Experiment No. 60 as a possible exception in Appendix, page 287.

J. Standard alcohol dose followed by 500 c. c. whole milk 1 hour after. Nos. 46 and 53.
K. Physical work on bicycle ergometer in alternate periods, Nos. 3, 5, 7, 9, 11, 13, and 15, after standard alcohol dose. Nos. 64 and 65.

For comparison with series K, there were two control experiments, Nos. 66 and 67, in which also the subject did external work on the bicycle ergometer at a rate of 1.3 large calories per minute.[a] The working periods were alternated with periods of psychological tests, except that both of the two preliminary periods consisted of psychological tests. Following the ingestion of the solution, periods 3, 5, 7, 9, 11, 13, and 15 were used for the physical work. The period of work in each case was 12 minutes, thus allowing enough time for the collection of the urine sample at the end. The three control experiments which are used for comparison with the other series, A to J, inclusive, were made near the center of the group of experiments and were performed on nearly consecutive days, i. e., February 9, 10, and 14; they are numbered in table 37 as 55, 56, and 57. In these control experiments, as in those for series K, the dose was 300 c. c. of grape juice diluted to a total volume of 1,000 c. c.

The schedule of measurements during the 15-minute experimental period regularly used throughout series A to K, inclusive, was as follows, including the time requirement for each:

1. Finger-movement speed for 10 seconds. One record made. 1 minute.
2. Code test. 50 letters transliterated. 2 minutes.
3. Pursuitmeter measurement. A 5-minute continuous test. 6 minutes.
4. Eye-movement velocity, 2 records. 2 minutes.
5. Station. Standing motionless for 2 minutes. 3 minutes.
6. Urine sample taken. Flask stoppered and marked. 1 minute.

Occasionally it was not possible to void urine at the end of the 15-minute period, but this happened only four or five times in the whole group of experiments. The urine was passed directly into graduated glass-stoppered flasks, the time was carefully marked on the flask immediately following collection, and the samples were kept in a refrigerator and usually analyzed within 24 hours. The analysis was made by the Widmark-Nicloux method and always in duplicate.[b] If duplicates did not agree closely, a third analysis was made. The value plotted for any period is usually the average of two closely agreeing determinations for the period. If there were two alcohol days in the series, as, for example, in series A, the results for corresponding times following the ingestion of alcohol were averaged, and it is this series of averages for the 14 or more samples following alcohol that has been plotted as the alcohol-urine curve. The value is always plotted midway of the collection period represented.

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[a] Experiment No. 68 was with alcohol and physical work, but since four blood samples were taken during its progress, it was not included in series K. Nos. 68, 69, and 70 were made for the purpose of examining the relationship between the alcohol concentrations in blood and urine. These concentration results have been reported; see Journ. Pharm. and Exp. Therapeutics, 1922, **20**, p. 277, figs 2, 3, and 4. This concentration relationship will be considered in the fore part of Chapter VI.

[b] For a discussion of this method of analysis, see Chapter VI, page 210.

METHOD OF PRESENTING RESULTS.

The data for these eleven series of experiments would amount in total to a large mass of tabular matter. The writer has therefore chosen to give the results in the form of condensed charts. For each series there is one figure which is really made up of six individual charts, i. e., those for station, pursuitmeter, eye movements (left and right), finger movements, and code test, respectively. The six small charts within one figure show the same alcohol-urine curve (designated "urine") and urine per minute curve. The three other curves marked "control," "alcohol," and "effect" are the varying features from chart to chart. The per cent scale at the extreme right of each chart applies to the "effect" curve, while the scale at the extreme left of the chart applies to "control" and "alcohol" curves and is in terms of the unit which has been used for the particular measurement illustrated as previously described in this chapter. The scale for the concentration of alcohol in urine is at the left in "mgm. per c. c.," and that for urine per minute is at the right in "c. c. per min." The values in the alcohol and control curves are plotted at the position which they represent in time in the experimental period. These periods are not numbered, but are indicated by the successive vertical ordinates in the chart, and the time following the ingestion of alcohol is indicated in minutes on the abscissa. The two zeros on the abscissa indicate the interval for the regular alcohol ingestion. The "minutes after ingestion" are counted from the right-hand zero, or the time when ingestion was completed, following which there was a 5-minute rest before tests were begun. The results for the eleven series employing 15-minute periods will be presented briefly and in the order outlined on page 181.

STANDARD AND POST-ABSORPTIVE EXPERIMENTS.

Series A.—In series A the conditions for the five earlier series in this chapter were used, with the exception that individual periods were 15 minutes in length and the experimental session lasted 4 hours. As shown in the various charts in figure 26, the maximal alcohol concentration in the urine is reached between 55 and 60 minutes after the completed ingestion of the dose and amounts to 0.45 mg. per cubic centimeter. From this value and after this time the concentration gradually declines. There is a prominent alcohol effect in station amounting to a decreased ability of about 39 per cent maximum which occurs 65 minutes after ingestion. From 125 to 215 minutes station is steadier than normal, i. e., there was a minus effect. The pursuitmeter also gives a minus effect at this time, but earlier shows the influence of the alcohol by poorer scores. The maximum is not prominent. The eye movements (left) show decreased velocity throughout, the maximal change, 15 per cent, occurring 60 minutes after ingestion. The eye movements (right) show a less percentage of change than those to the left, but always a slower velocity after alcohol, the maximal change being 12 per cent 75 minutes after ingestion. Finger movements are slower by about 3 per cent, with no well-marked maximum. The effect on the code test was a decrease in rate of transliteration of about 11 per cent 25 minutes after ingestion and an average decrease larger

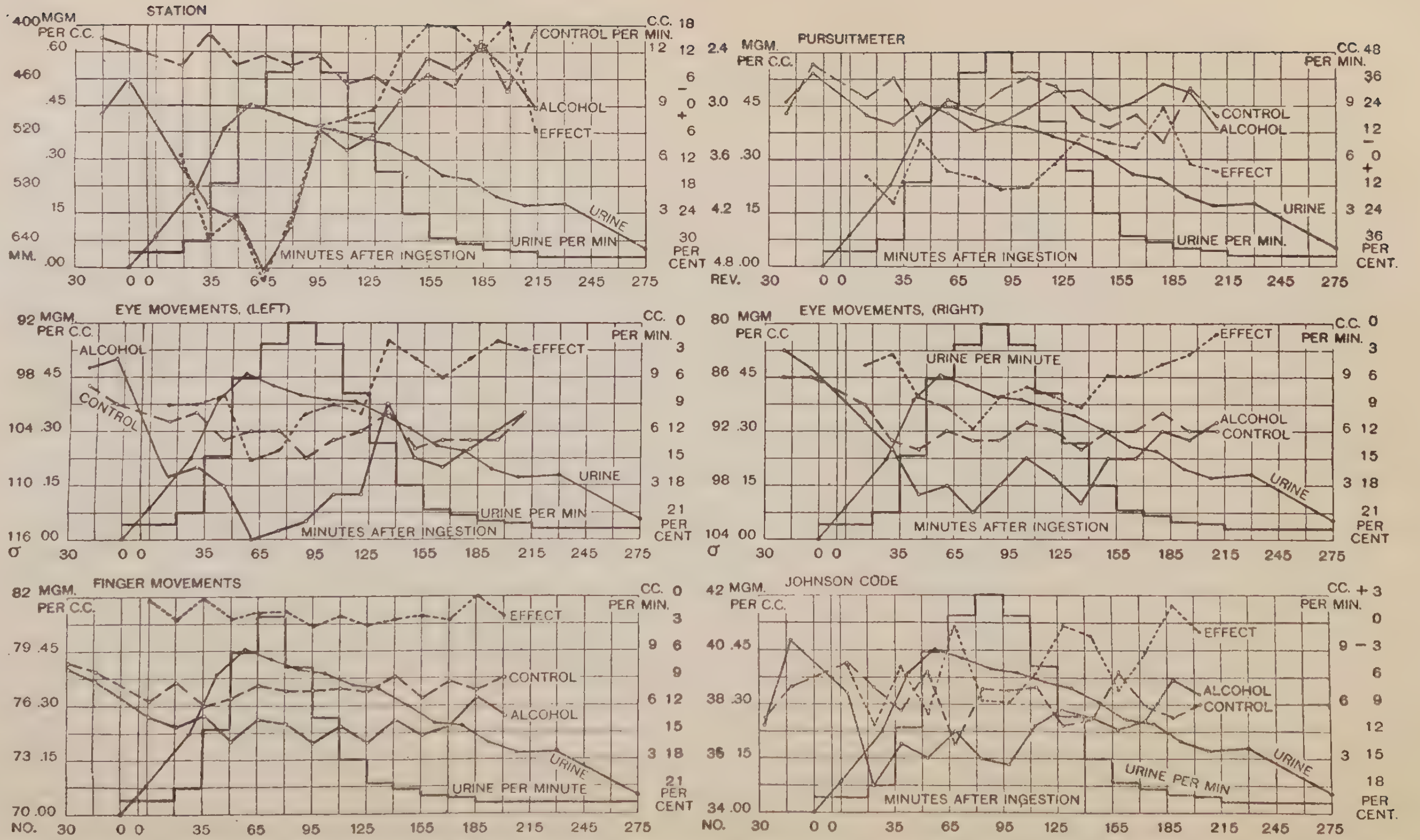

FIG. 26.—Effect of Alcohol on Various Measurements Made at 15-minute Intervals and Compared with Concentration of Alcohol in the Urine (Series A).

Standard conditions, i. e., experiments performed in the afternoon following a very light lunch. The alcohol was a 2.75 per cent solution by weight, diluted by grape juice. The liter of beverage was taken between periods 2 and 3, and the experiments were continued about 3½ hours, divided into 14 periods.

than 5 per cent until 185 minutes, but the curves appear erratic. In two charts, those for station and eye movement (left),[a] the prominent maximal effects are practically synchronous with the maximal alcohol-urine concentration, while with the pursuitmeter and code the maxima come a little earlier, and with eye movements (right) and finger movements they come a little later than in the urine curves.

Series B.—The post-absorptive condition was the distinguishing feature of series B, the results of which are given in figure 27. The alcohol-urine curve is similar to the one in the preceding figure, reaching the same maximum, 0.45 mg. per cubic centimeter, but at a later time, i. e., 70 to 75 minutes, instead of 55 to 60 minutes as in series A. There is no apparent plateau, since the alcohol concentration begins to decrease immediately after reaching its maximum, although not so rapidly as in series A. The station test shows poorer efficiency by a maximum of about 25 per cent, which occurs at 65 minutes. In the latter part of the curve the effect is erratic and in three instances the values have the minus sign. In the pursuitmeter results the scores are larger after the alcohol, except at the last of the experiment. The decrease in ability produced by the alcohol is 32 per cent at 30 minutes. From this point there was rapid recovery and then progressive decline to 28 per cent at 105 minutes after ingestion. The alcohol curve for eye movements (left) shows a particularly erratic value at 75 minutes. All the periods indicate slower velocity, with an effect of 10 per cent at 30 minutes. There was a less positive change in eye movements (right). Some of the periods in the latter part of the experiment show larger than 3 per cent, but the amount is variable. The finger movements change but little until 110 minutes after ingestion of the dose, when they are characteristically about 2 per cent slower. In the code test the maximal effect of about 12 per cent at 83 minutes after the ingestion of the dose closely follows the maximal concentration in the urine, but there was nearly as large an effect in the first period, 20 minutes after ingestion.

For the post-absorptive series (B) as a whole, the effect curves which have been found by the difference method appear somewhat fluctuating, although in nearly all cases indicating decreased efficiency. Station, pursuitmeter, adductive eye movements, and code test all show early pronounced effects preceding or about coincident with the maximal alcohol concentration in the urine. The prompt downward tendency of the alcohol curves in the first 30 minutes after ingestion while the concentration is rapidly rising is characteristic of these results and is also found in the preceding figure. In general, the effect is larger in the first hour following ingestion with series A, in which the alcohol was taken in the afternoon 2 hours after a light lunch than it is for series B with the subject in a post-absorptive condition. After the first hour the effect is somewhat larger in series B and more consistently in one direction. The alcohol concentration in the urine is also higher during the last two hours in series B than in series A.

VARIATIONS IN PERIOD OF INGESTION AND IN QUANTITY TAKEN.

Series C.—For series C, the regular 1-liter dose was divided into three equal portions; one-third was taken at the usual time for ingesting the

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[a] Left and right in referring to eye movements mean, respectively, adductive and abductive.

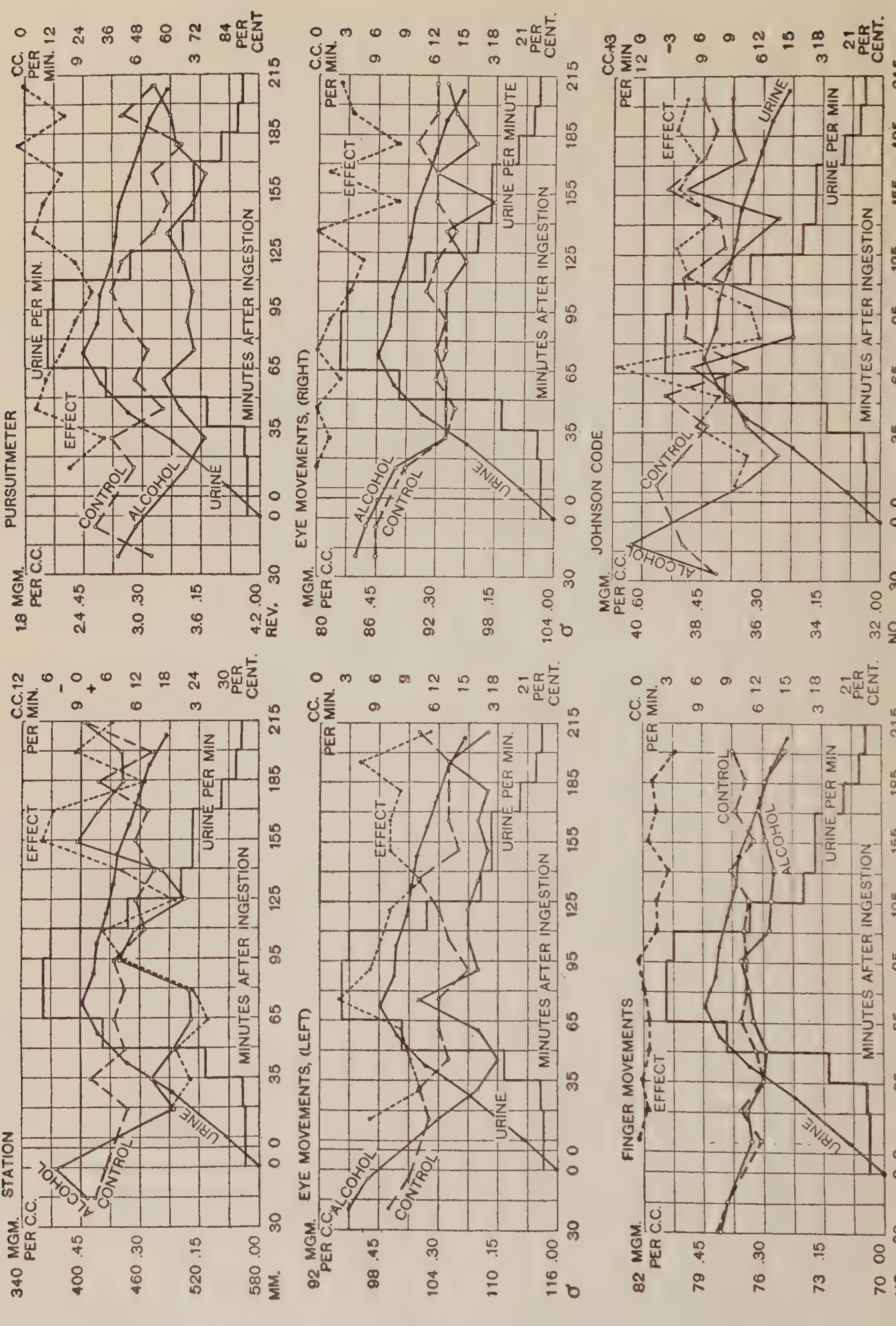

Fig. 27.—Effect of Alcohol on Various Measurements Made at 15-minute Intervals and Compared with Concentration of Alcohol in the Urine (Series B).

dose, the second was taken 35 minutes later, and the last third at 65 minutes. From figure 28 it will be seen that the maximal concentration did not occur until 115 minutes after the ingestion of the first third and the concentration was 0.43 mg. per cubic centimeter. The rate of increase in the alcohol concentration in the urine was but slightly more rapid than the rate of decrease, while in the two preceding figures there has been considerable difference. The block curve for urine per minute is changed in character in this series, showing, if not a double top, certainly a widened area where the diuresis was fairly large. The general alcohol effect is not so strong as in the two former series, e. g., in station the maximal effect (decreased ability) is only 12 per cent as compared with 39 and 25 per cent for series A and B. The pursuitmeter, eye movements (right), eye movements (left), and code test all show their maximal alcohol effects relatively late in the experiment, just as the peak of the urine-alcohol curve came later than in the former series. The finger movements exhibit quite a regular change, gradually increasing, but with no prominent maximal effect. As a result of the division of the dose and the extension of the ingestion period another hour, the intensity of the alcohol effect has been reduced and delayed, the rate of increase of alcohol concentration in the urine is considerably decreased, and the maximum is slightly decreased and reached at a later time.

Series D.—In series D, the regular 1-liter dose containing 2.75 per cent of alcohol was taken as usual, and, in addition, an extra half-liter of this alcohol solution was ingested in ten 50 c. c. portions. One such portion was taken at the beginning of each period from 7 to 16, inclusive, just previous to the finger-movement test. No time allowance had to be made for the ingestion of these 50 c. c. doses. The results of this series are shown in figure 29 and represent data obtained on but one day. It is apparently an idiosyncrasy of these results that the maximal concentration of alcohol in the urine, which occurs about 60 minutes following the ingestion is 0.36 mg. instead of the 0.45 mg. which appears in the former series. Period 7, which commenced 65 minutes after the ingestion of the standard dose, marks the time when the taking of the extra half-liter began. It is observable that there is no fall in the urine-alcohol curve, which, on the contrary, tends to rise until the sixteenth period. A urine sample collected somewhat after the psychological measurements of period 16 were completed shows a slight fall from the maximal concentration of 0.50 mg. which was obtained in that period.

The alcohol effect continues prominent in the station test up to 125 minutes after ingestion and then changes promptly to the opposite sign. With the pursuitmeter there is a maximal effect in the ninth period which amounts to about 49 per cent. The effect curve in this case appears fairly regular, first gradually reaching its maximum and then retreating in general from it. This is unusual, as most effect curves in these series exhibit more than one prominently low point. The curve for eye movements (right) shows somewhat similar results to those for the pursuitmeter, the greatest effect being in the ninth period. The alcohol effect on the eye movements (left) is fairly large but of varying amount, with a maximum in the seventh period of 17 per cent slower movement. The finger movements give the

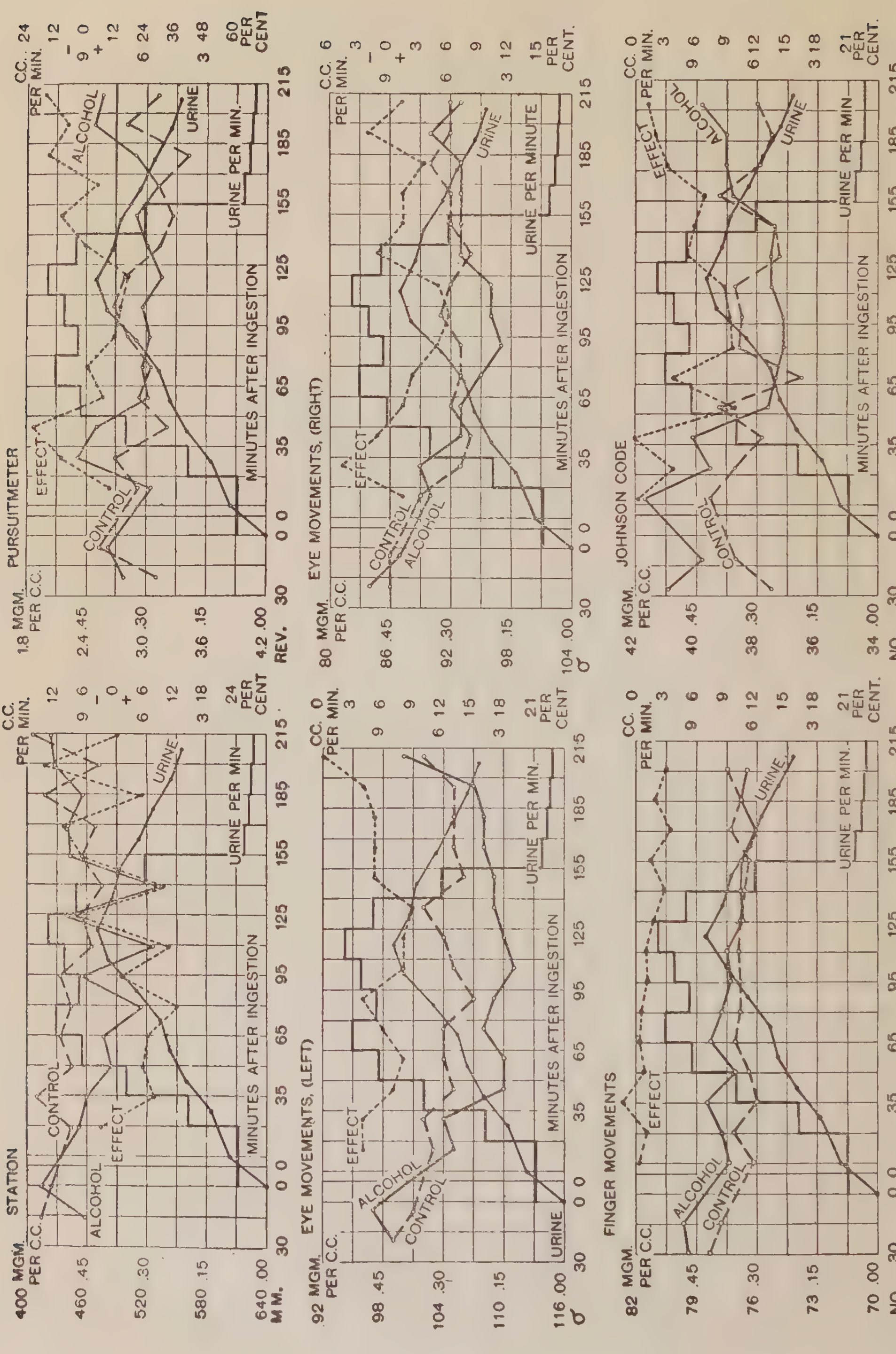

FIG. 28.—Effect of Alcohol on Various Measurements Made at 15-minute Intervals and Compared with Concentration of Alcohol in the Urine (Series C).

The standard 1-liter dose was taken in three equal portions separated by 30-minute intervals. The alcohol-urine curve therefore reached its highest

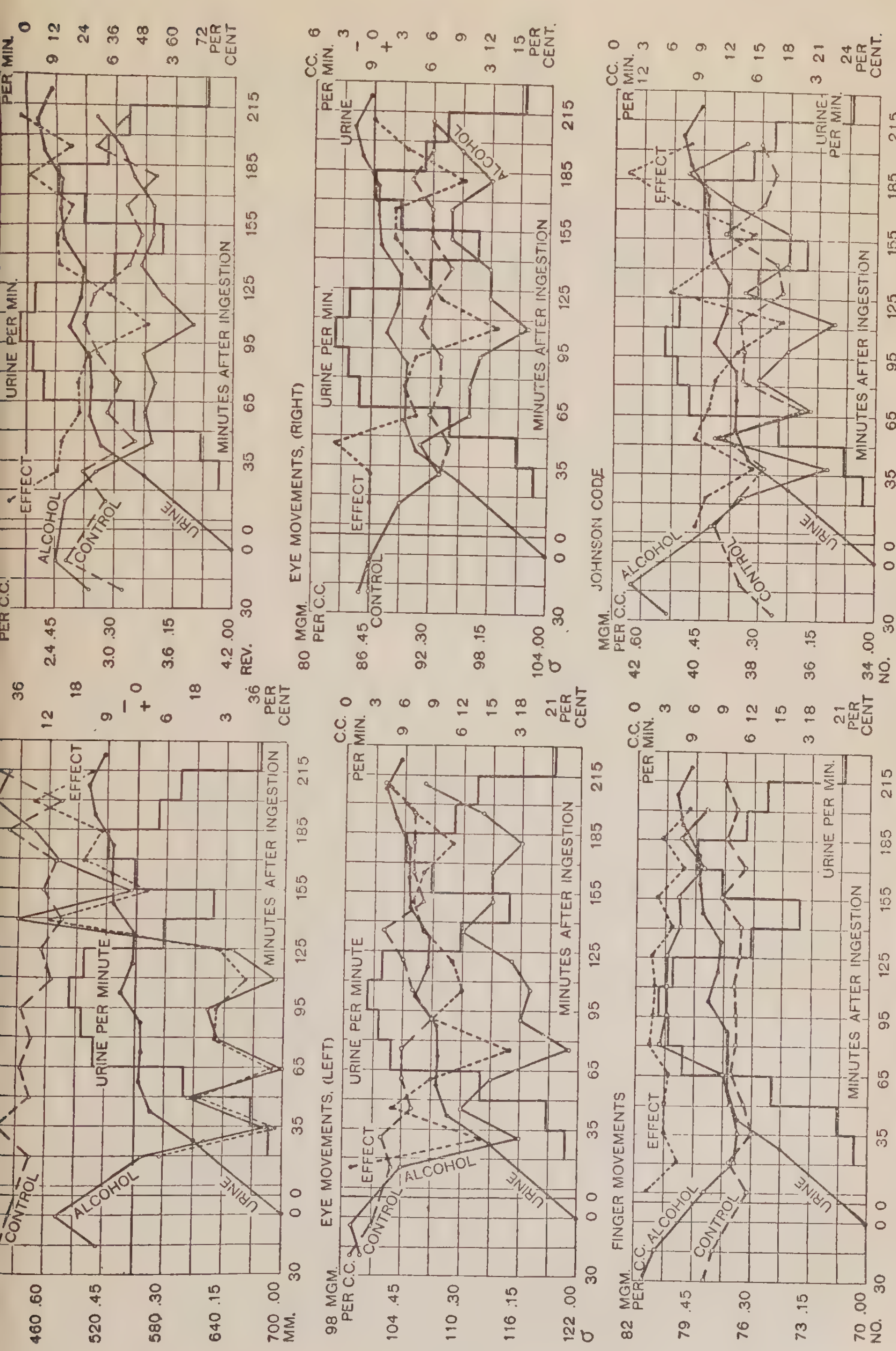

FIG. 29.—Effect of Alcohol on Various Measurements Made at 15-minute Intervals and Compared with Concentration of Alcohol in the Urine (Series D).

Additional 500 c. c. of standard dose taken in ten 50 c. c. portions at beginning of each period from periods 7 to 16, inclusive. The total amount of alcohol ingested was therefore 41 grams. The time of ingestion extended over a 3-hour period.

usual results. They are all minus, with an average of about 3 per cent. Actually the alcohol curve for number of finger movements executed is slightly above that of the control curve. The difference between the preliminary level and the alcohol level is characteristic of the alcohol influence in this instance. The results for the code test likewise indicate a definite fall in the performance from the preliminary to the alcohol level, and therefore indicate decreased efficiency.

The ingestion of an additional half-liter of the regular alcohol solution over a period of 2½ hours has resulted in an alcohol-urine curve which has no well-marked maximum, but continues to rise gradually between 40 and 215 minutes after the first ingestion. Under these circumstances, the alcohol effect is still strongest in the early part of the experiment and just following the time when the urine concentration first reached the level from which it later slowly changes. The alcohol effect for this series is, in general, of about the same magnitude as that found in series B; the average effect in the first hour of series D agrees fairly well with the results shown in both series A and B.

Series E.—The conditions for series E were like those of the preceding series, except that the additional amount taken of the alcohol solution was still larger, 900 c. c. in 100 c. c. doses at the start of periods 8 to 16, inclusive. Figure 30, which graphically shows the results of this series, indicates a higher initial rise in the alcohol concentration in the urine than has been found in any of the preceding charts. As in series A, the curve rises abruptly but reaches a height of 0.04 mg. above that attained in the earlier series, the concentration 1 hour after ingestion being 0.49 mg. per cubic centimeter. The alcohol concentration begins to fall before the additional doses were started at 80 minutes, but is about stationary at 0.45 mg. per cubic centimeter between 95 and 125 minutes after ingestion. Then it rises to a new high point of 0.62 mg. per cubic centimeter in the fourteenth period and finally reaches 0.67 mg. per cubic centimeter at the end of the sixteenth period, i. e., at 215 minutes after ingestion. The 50 c. c. portions taken in addition to the regular dose in series D were slightly more than enough to keep the alcohol-urine curve level and the 100 c. c. portions in series E cause a prominent rise as the experiment progresses.[a]

The alcohol effect in series E is prominent in the station test, amounting to 33 per cent at 65 minutes, thus corresponding with the initial high point in the urine curve. The effect is not constant, becoming definitely less even to the point of disappearance, with −1.6 per cent in the ninth period. Contrary to what has been found in series A to D, near the end of the experiment, the alcohol effect on station was again prominent, with values of 35, 20, and 17 per cent for periods 14, 15, and 16, respectively. Similar results appear in the pursuitmeter data, with a large alcohol effect throughout, especially in periods 7, 9, and 15, with percentages of 45, 55, and 45. Both eye-movement charts show a prominent alcohol effect in the direction of decreased velocity, which in both cases seems to increase progressively with the increase in the alcohol concentration in the urine. The finger-move-

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[a] See Widmark, Studies in the concentration of indifferent narcotics in blood and tissues. Acta Medica Scand. 1919, 52, p. 121. A discussion is given of the rate of fall in the concentration curve, or the amount necessary to maintain a constant concentration as an expression of the individual's tolerance for alcohol.

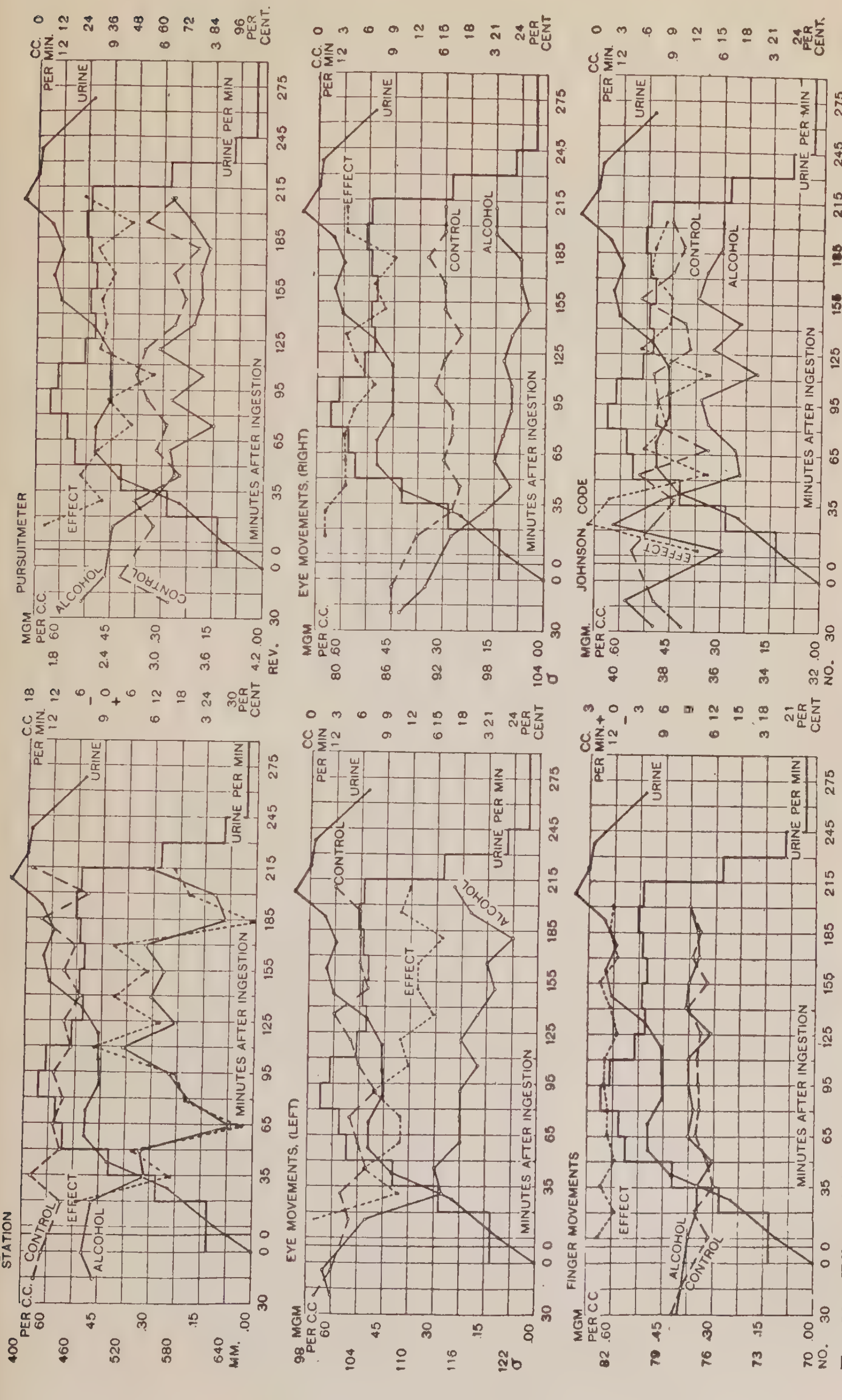

FIG. 30.—Effect of Alcohol on Various Measurements Made at 15-minute Intervals and Compared with Concentration of Alcohol in the Urine (Series E).

Additional 900 c. c. of standard dose taken in nine 100 c. c. portions at beginning of each period from periods 8 to 16, inclusive. The total amount of alcohol taken was 52.2 grams. The time of ingestion extended over a 2¼-hour period.

ment measurement gives an even curve and seems curiously unaffected by the alcohol. There is here no single value as large as 2 per cent. The code results are irregular, especially in periods 4 and 5, but otherwise show a decrease of approximately 8 per cent which continues until the end of the experiment.[a]

We may conclude, therefore, that when an additional 900 c. c. of alcohol solution is taken in small portions over a period of 2¼ hours, after the previous ingestion of a liter of the same solution, the concentration of the alcohol rises more or less continuously until the end of the experiment. The effect of the alcohol on both eye-movement measurements tends to show a continuous increase as the alcohol concentration in the urine increases. Station and the pursuitmeter tests give a stronger effect near the end of the experiment than in other series when additional alcohol solution has not been taken. Thus, the general alcohol effect for series E is not especially altered in the first hour or hour and a half but, in contrast to the effect in the four series which precede it, is prominent in the third and fourth hours after ingestion.

Series F.—There was only one day (December 29, 1920, experiment No. 44) when 2 liters of the regular grape-juice-alcohol solution were taken at the beginning of period 3. The ingestion occupied an interval of 16 minutes in this instance, and was probably about as large a volume of solution as the subject could take within such an interval. The complete dose contained 55.0 grams of ethyl alcohol which was, as usual, 2.75 per cent of the solution by weight. The results of this experiment (series F) are given in figure 31. The scale is the same as in the previous charts. The alcohol effect for each measurement is so pronounced and so clearly to be seen from the charts that but little comment is required.

Notwithstanding the large ingestion of liquid, perhaps in consequence of it, the diuresis was especially small in the first 2 hours after the ingestion and in certain instances amounts of urine sufficient for analysis could not be obtained. The alcohol concentration apparently reached its highest point (0.92 mg. per cubic centimeter) 95 minutes after ingestion. The rise was rapid, and after the peak was reached a decrease soon began to take place. In this instance the falling concentration was measured over a period of 6 hours after the psychological measurements were finished, but this prolongation of the curve of decline is not shown in the charts. The maximum in the diuresis curve came 45 minutes after the completion of the psychological measurements, that is, more than 4 hours after the complete ingestion.

The maximal effect on station was an increased sway of 91 per cent in period 8, i. e., at 95 minutes. This was the largest percentile change found for any measurement in all the 11 series. In the pursuitmeter test it will be observed that the effect amounts to 68 and 66 per cent in periods 8 and 10, at 90 to 120 minutes. The alcohol effect ranges from 11 to 20 per cent for eye movements, left, the latter value being in period 6, while periods 7 and 8 both show a decrease in speed of 18 per cent. For eye movements, right, the range is from 10 to 32 per cent. The finger movements supply the only instance here of improved performance; this was +1.2 per cent in period 3.

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[a] For notes on subjective effects, see Appendix, page 287.

From periods 10 to 16 the decrease in number of finger movements averaged nearly 5 per cent, which is unusually large for this measurement. In periods 3 and 4 of the code tests there was an average decrease in ability of 24 per cent and then a fairly uniform effect of 15 to 18 per cent for 2½ hours.

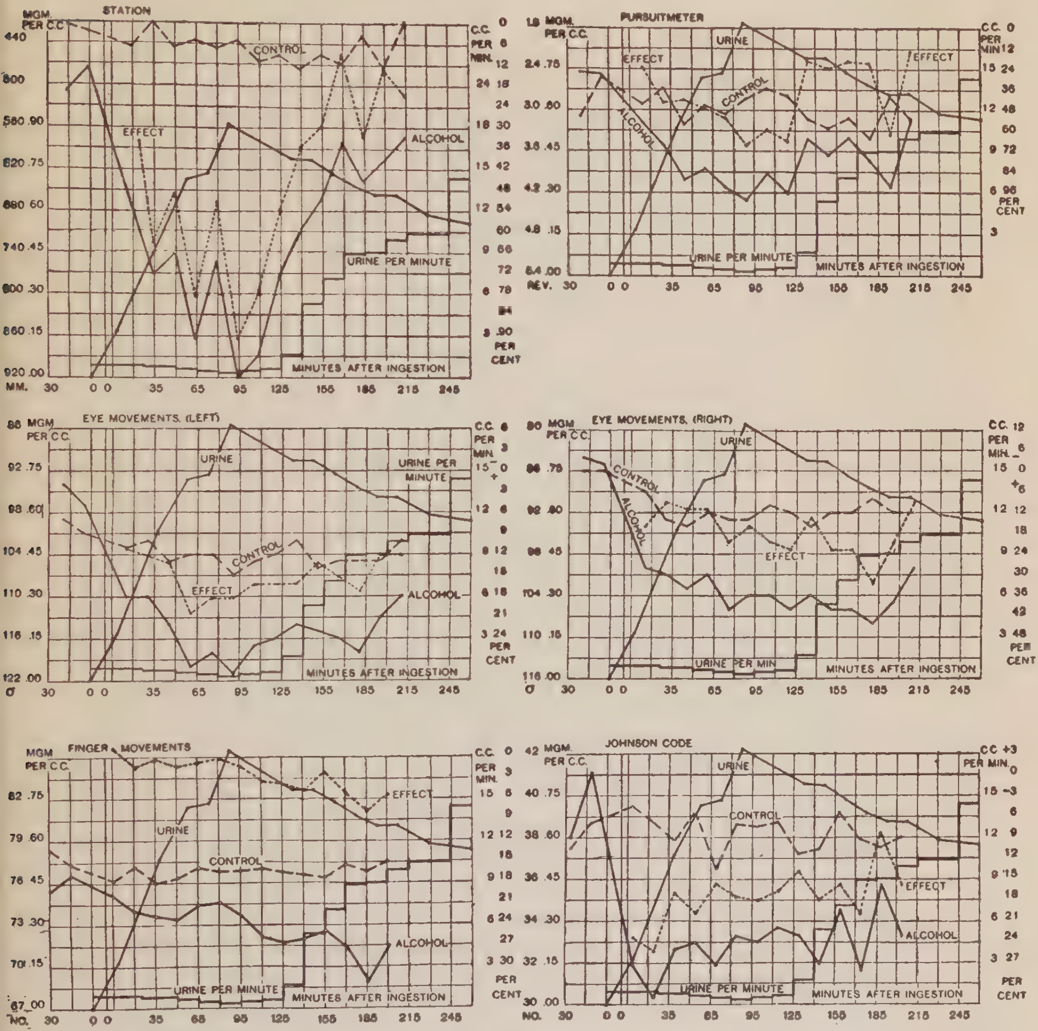

FIG. 31.—Effect of Alcohol on Various Measurements made at 15-minute Intervals and Compared with Concentration of Alcohol in the Urine (Series F).

A dose double that of Series A, i. e., 2,000 c. c., was taken within 20 minutes; otherwise the conditions were standard. The results are for but one day (experiment No. 44).

In the third and fourth hours after the ingestion of the double dose, the effect of alcohol decreased somewhat as a whole. At this time the concentration curve had begun to fall, but was still at a level considerably higher than the usual maximal concentration from taking the regular 1-liter dose, as found, for example, in series A. Although with the six measurements the effect of alcohol varies considerably, the average values may be compared. In the third hour after the ingestion of the 2 liters (periods 11, 12, 13, and 14), the average effect for all six measures still amounts to 17.6 per cent, whereas in the first hour after ingestion (periods 3, 4, 5, and 6) in series A, B, and D, the effects were but 9.7, 9.2, and 9.9 per cent, respectively. Thus, while the alcohol effect is decreasing in the third hour of series F, it is still somewhat larger than the general effect in the first hour following the usual dose.

The conclusion from this double-dose experiment is that the maximal concentration reached in the urine was twice that which follows upon taking the 1-liter dose, the alcohol effect was more than twice as strong, its maximal intensity tended to correspond to the maximal concentration in most measurements, and the general course of events was similar to that following the regular dose, except that the changes were magnified. Further, it is to be observed that 2 liters of alcohol solution can be taken by a common-sized man within less than half an hour, and that if the stomach is empty and the alcohol solution contains as much as 55 grams of absolute ethyl alcohol, the effect on the efficiency of the man is pronounced, ranging from 5 to 90 per cent with various neuro-muscular measurements.[a]

EFFECT OF PRECEDING OR FOLLOWING ALCOHOL INGESTION WITH OTHER LIQUIDS.

Series G and H.—There were two series, G and H, in which non-alcoholic liquid preceded the taking of the regular dose. The results are given separately in the usual form of charts in figures 32 and 33. In series G, 0.5 liter of water was taken 1 hour before the alcohol was ingested, while in series H, 0.5 liter of whole milk was drunk exactly 1 hour before the ingestion of the alcohol. The two alcohol-urine curves reach substantially the same maximal concentration, but the maximum is reached more promptly after the milk than following the water, that is, at 50 minutes in one case as compared to 80 minutes after ingestion in the other.[b] The fall is likewise a little more prompt after the milk. The preliminary level of diuresis was higher with the water than with the milk. In general, the alcohol effects are very closely the same for both series. It happens that the maximal alcohol effects for station, eye movements (left and right), and finger movements are smaller in series H with milk, but our experiments are too few to assess the significance of this. However, the taking of liquid before the alcohol did modify the alcohol effect considerably and there was in each series an early return to something approximating normal performance. The average alcohol effect for all measurements in the first hour following ingestion in these series is 5.3 per cent in both cases as compared to something above 9 per cent in the first hour for series A, B, and D, as previously

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[a] See the subjective account in the Appendix, page 287.

[b] The 0.5 liter of water was given in experiments Nos. 47 and 49. In the latter the results of the analyses for periods 3 to 8, were 0.087, 0.320, 0.420, 0.435, 0.409, and 0.385 mg. per cubic centimeter. In the former experiment, the similar values for alcohol concentration were 0.087, 0.270, 0.242, 0.245, 0.316, and 0.315 mg. per cubic centimeter. There is a wide disparity between the two sets of results, but no error could be proved for experiment No. 47 to justify discarding it.

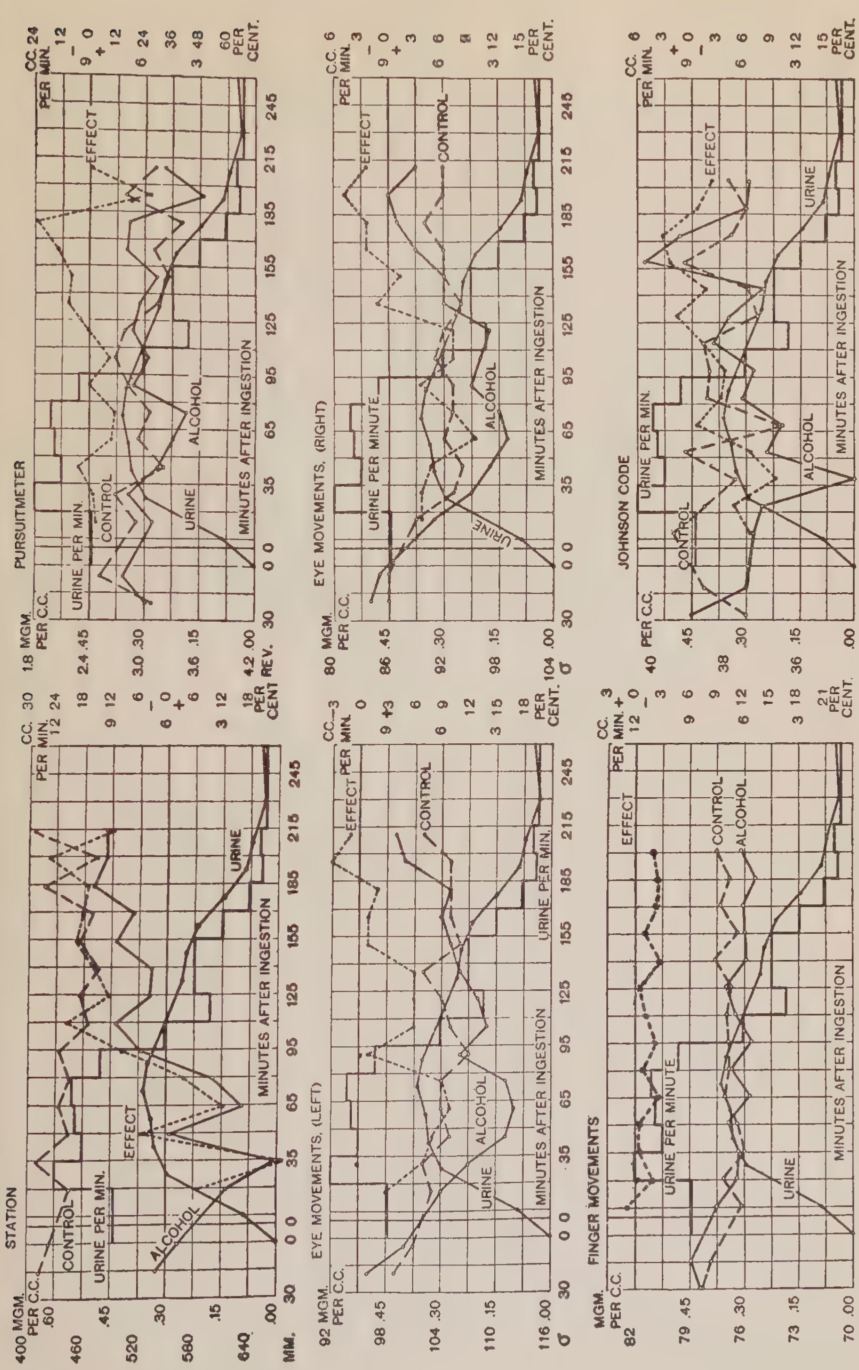

FIG. 32.—Effect of Alcohol on Various Measurements Made at 15-minute Intervals and Compared with Concentration of Alcohol in the Urine (Series G).

Standard conditions, except that 500 c. c. of water were taken 1 hour before the alcohol dose.

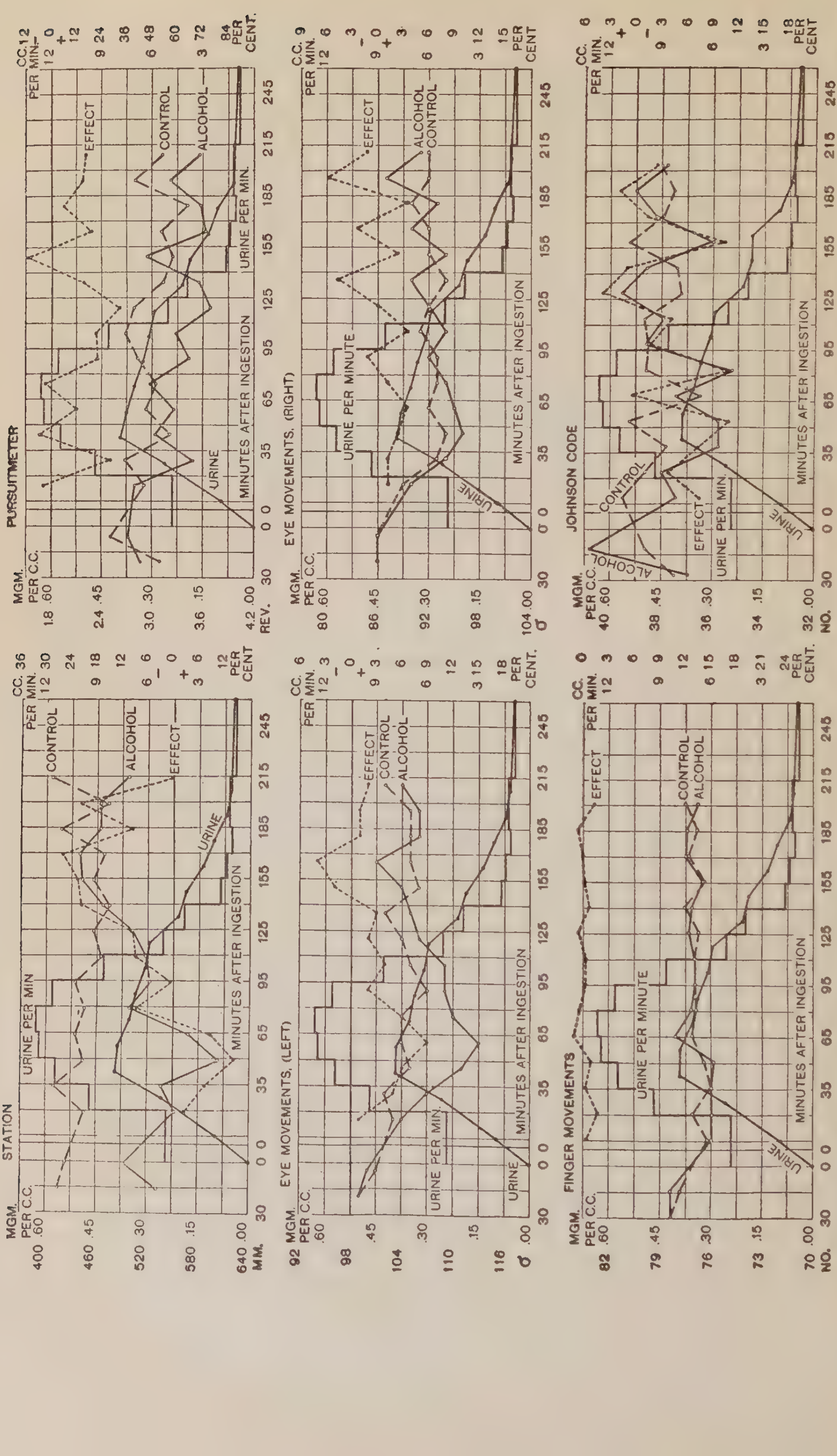

FIG. 33.—Effect of Alcohol on Various Measurements Made at 15-minute Intervals and Compared with Concentration of Alcohol in the Urine (Series H).

Standard conditions, except that 500 c. c. of whole milk were taken 1 hour before the alcohol dose.

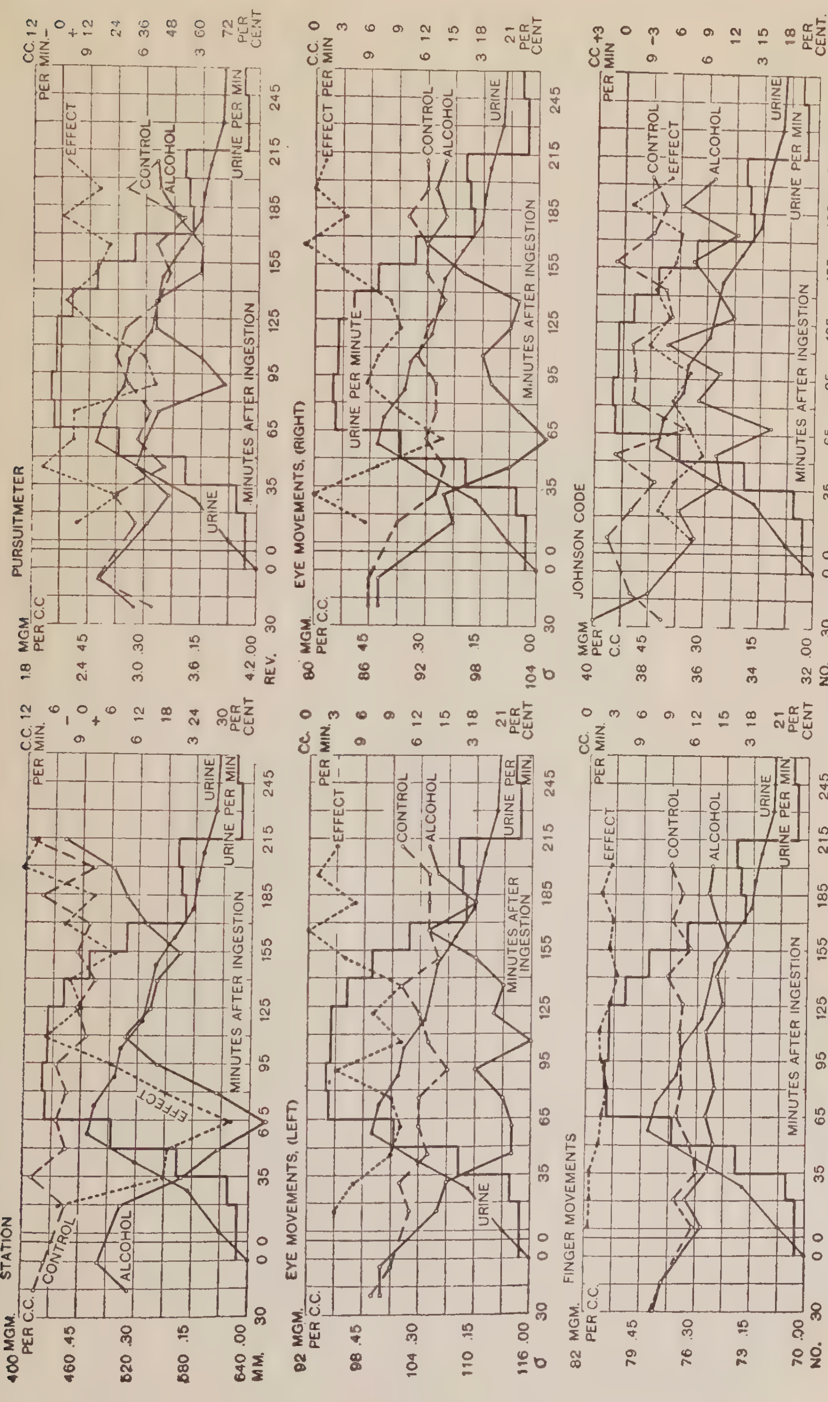

Fig. 34.—Effect of Alcohol on Various Measurements Made at 15-minute Intervals and Compared with Concentration of Alcohol in the Urine (Series I).

Standard conditions, except that 500 c. c. of water were taken 1 hour after the alcohol dose.

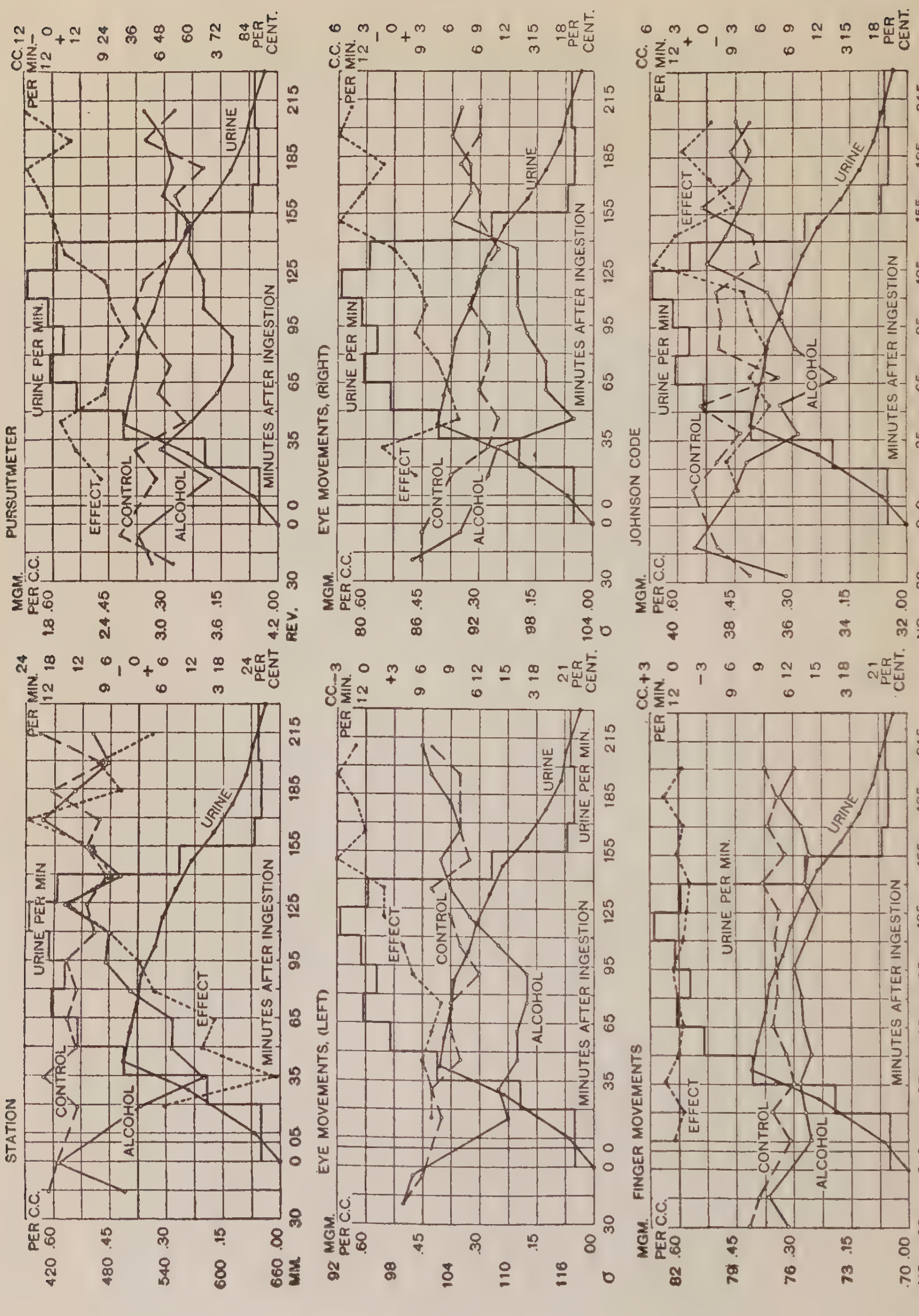

FIG. 35.—Effect of Alcohol on Various Measurements Made at 15-minute Intervals and Compared with Concentration of Alcohol in the Urine (Series J).

noted. The taking of the half-liter of liquid, either water or milk, served to reduce substantially the effect of the alcohol subsequently ingested, probably on account of the dilution, though the reduction in the height and area of the alcohol-urine curves is not seen to be particularly prominent when these curves are compared to that obtained in series A.

Series I and J.—In two series, I and J, extra non-alcoholic liquid was given 1 hour after the completed ingestion of the standard dose. In series I, 0.5 liter of water was taken, and in series J, 0.5 liter of whole milk. The time of taking this extra liquid was at the beginning of experimental period 7, or 65 minutes after the ingestion of the liter of 2.75 per cent alcohol. The results are shown in figures 34 and 35. The maximal concentration reached in both instances was practically the same, i. e., about 0.42 mg. per cubic centimeter, but in this pair of experiments, also, the maximum is reached somewhat earlier in one case than in the other. Here, however, this difference can not be due to the extra liquid ingested, since the milk or water was taken later. It must therefore be due to a variation in the physiological factors which pertain to the absorption and utilization of alcohol. Two experiments performed under the same or supposedly the same conditions rarely give exactly superimposable curves for the alcohol concentration in the urine. The variations from day to day and the causes for these differences are yet to be studied.

The alcohol effect in both series I and J, when extra liquid was taken 1 hour after ingestion, is more prominent than in series G and H, when the same amount of liquid was taken 1 hour previous to the alcohol. Both series I and J show an average alcohol effect for all measures of about 8 per cent in the first hour after ingestion. In series I with the water, the average effect is 9.1 per cent in the second hour, 5.2 per cent in the third hour, and 1.6 per cent in the fourth hour (periods 15 and 16). In contrast, it is found in series J with the milk that the average effect in the second hour is 5.9 per cent, in the third hour, −2.8 per cent, and in the fourth hour, −2.2 per cent. The latter two values signify a condition better than normal. The taking of milk reduced the alcohol effect on the psychological measurements, but did not particularly change the course of the alcohol-concentration curve for urine. The alcohol effects are, in general, considerably larger when the additional non-alcohol liquid was taken after the dose than when taken before it by an equal interval of time.

In an important study of the alcohol concentration occurring in the blood of dogs after various solutions had been given, Mellanby[a] investigated the influence of drinking water and milk, either mixed directly with the alcohol solution or taken 2 hours previously. He found that the preliminary ingestion of water considerably increased the rapidity of absorption of the alcohol. He states:[b]

> "Milk is the most effective foodstuff for delaying absorption of alcohol into the blood. It is almost equally effective whether mixed with the alcohol or drunk 2 hours before the alcohol. Its action is quite independent of the

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[a] Mellanby: Alcohol, its absorption into and disappearance from the blood under different conditions. Med. Research Com., Sp. Rept., Ser. No. 31, London, 1919, p. 22.

[b] *Ibid.*, p. 26.

dilution factor, although dilution with milk naturally acts in the same way as dilution with water."

Mellanby gave the dogs rather large quantities of alcohol, approximately 4.0 c. c. of absolute alcohol per kilogram of body-weight, which is roughly eight times the amount used in our experiments. He also employed 0.5 liter or more of milk with a dog weighing 10 to 14 kg., while we have used 0.5 liter of milk with a man weighing 70 kg. For these reasons it is questionable whether our results can be rightfully used for comparison.

INFLUENCE OF PHYSICAL WORK ON ALCOHOL EFFECT.

Series K.—In the eleven comparisons made with 15-minute periods extended for a total duration of 4 hours, the last set (series K) concerned the influence of physical work on the alcohol effect. The results are incorporated in charts of the usual form in figure 36. These experiments have their own pair of control days when muscular work with the bicycle ergometer[a] was done at the rate of 1.3 large calories per minute of external work (60 pedal revolutions per minute) in alternate periods after the taking of the non-alcoholic dose. The entire 15-minute period was given over to the muscular work, except for the time allowed for the collection of the urine sample. Periods 3, 5, 7, 9, 11, 13, and 15 were devoted to the muscular work; in the other periods, the group of tests was used in the regular way. The plotted points for the psychological measurements in the alcohol and control curves following the dose are therefore only half the usual number. The alcohol and control curves frequently overlap or cross each other in this series. The alcohol effect is in the characteristic direction, but is small as compared with series A and B. The regular small effect on the pursuitmeter measurement and the prominence of negative results in both eye-movement charts are noteworthy. The average for all measurements in the first hour, which in this case would include only periods 4 and 6, is a decrease of 3.8 per cent in efficiency. The average for the second hour, periods 8 and 10, is 5.5 per cent, and in the third hour, 1.5 per cent.

Judging from these four experiments, two of which were control, the alcohol effect, although somewhat reduced, does not disappear when a medium amount of physical work is performed at regular intervals following the ingestion. According to the results of these experiments, the factor of physical work influences the alcohol results less than the preliminary ingestion of liquid (series G and H) or the taking of 500 c. c. of milk an hour after the dose (series J). Also, it is to be observed that in the last 2 hours of series K the effect curves do not rise so prominently to negative results, i. e., better efficiency than normal as found in some of the preceding figures. The concentration of alcohol in the urine, however, does not appear to be greatly changed by the physical work.[b]

NOTE A.—As in the series of 30-minute experiments on *Mow,* discussed in the earlier part of this chapter (see p. 138), so likewise in these several sets of experiments employing 15-minute periods, the total area of sway in the station test has been computed. The results are essentially the same in direction as when the alcohol effect on station is measured by the number of millimeters of movement read from

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[a] Benedict and Cady, Carnegie Inst. Wash. Pub. No. 167, 1912.

[b] Notes on the subject's impressions of these experiments may be found in the Appendix, page 288.

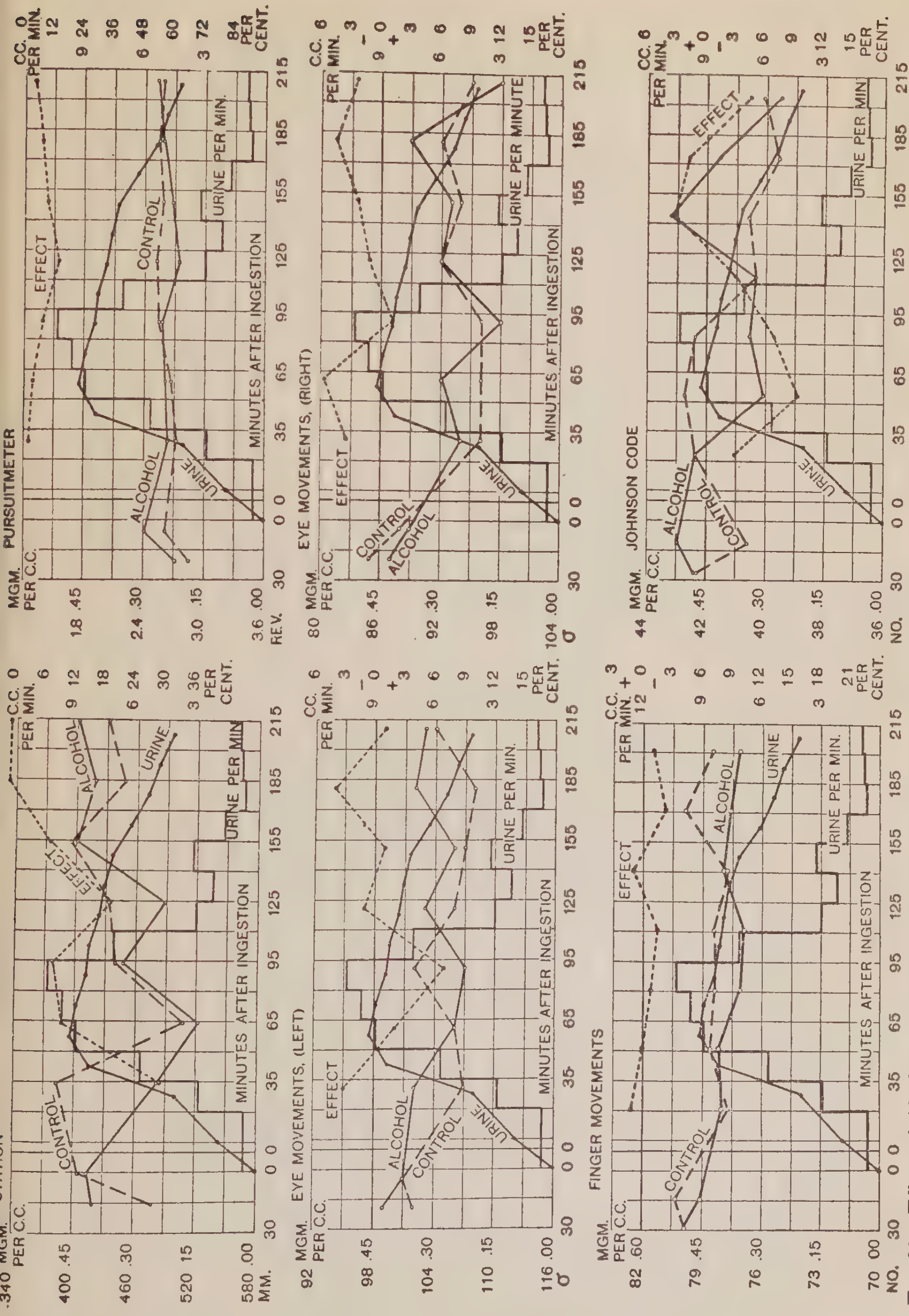

FIG. 36.—Effect of Alcohol on Various Measurements Made at 15-minute Intervals and Compared with Concentration of Alcohol in the Urine (Series K).

In the alternate periods of the experiments, physical work was substituted for the psychological measurements.

the movement adders. In terms of per cent, the effect on area is somewhat greater, but the results show more deviation between successive series. The chief fact, significant for our discussion, is that the subject did not, throughout all these series of experiments, learn to control himself so that he could avoid the greater swaying excursions which follow the taking of alcohol. The test continued to the end to show clear evidence in both amount and area of sway of the influence of the alcohol factor on the coordinations involved when the subject tried to stand motionless with the eyes closed. The amplitudes of the finger movements were also measured in series A to K, inclusive, following exactly the same routine as was used for the finger-movement records of the alcohol series described (p. 146) in this chapter. In the 15-minute periods, only one finger-movement record was made in place of the two records made in the 30-minute periods. The results obtained with *Mow* in the five series of experiments with 30-minute periods are confirmed by these later measurements. The finger-movement amplitude was considerably decreased, especially in the first 2 hours after the alcohol ingestion and the coefficient of variability of the finger movement was increased. As an example, the final results may be given for series A, which was the standard experiment with 15-minute periods. The alcohol effects for experimental periods 3 to 16 in order are decreased amplitudes of 22, 26, 22, 39, 35, 35, 26, 35, 26, 22, 22, 17, 22, and 22 per cent. All the values are minus. The alcohol effect for the variability of the finger-movement amplitude in terms of coefficient of variability for the same series and periods in order are 13, 15, 16, 30, 36, 73, 68, 30, 54, −1, 44, −7, 32 and 12 per cent, these all being increases except in periods 12 and 14, as noted. With the double dose, series F, the decrease in amplitude in periods 9, 10, and 11 was −33, −43, and −43 per cent. The corresponding increases in variability were +137, +171, and +133 per cent.

Conclusions as to Influence of Dilute Alcohol Under Varying Conditions.

Experiments were made to ascertain the influence of various conditions of dosage on the intensity of the alcohol effect. These survey experiments were all conducted on the same individual, *Mow;* they always continued 4 hours and were divided into 15-minute periods. Five neuro-muscular measurements were repeated in each period, and usually a urine sample was obtained for analysis of alcohol content. A composite curve or numerical summary can not be given, by reason of the variety of conditions used.

1. The generalized result of the 11 series of experiments with 2.75 per cent alcohol is that the subject's efficiency in all the tests used was regularly poorer than normal in the 2 hours following the ingestion of the alcohol dose regardless of experimental conditions. There was at least no prominent development of alcohol tolerance.

2. The different processes measured exhibit the alcohol effect in terms of percentage change to different degrees. The ability to stand without swaying is most affected and the speed of tapping or finger movement least. In general, the relative magnitude of the effect on the various measurements in the first 2 hours after alcohol corresponds well with the results obtained in the five series of experiments on the same subject reported in the first part of this chapter.

3. The intensity of the alcohol effect is decreased by the ingestion of non-alcoholic liquid taken 1 hour before or 1 hour afterwards, or by the performance of physical work of moderate intensity after taking the alcohol.

The effect is also decreased if the standard dose (1 liter of 2.75 per cent alcohol by weight) is divided and taken in portions during the period of 1 hour instead of ingested within 10 minutes. A double dose taken as one portion considerably increases the intensity of the effect and to a less extent prolongs its duration.

4. The duration of alcohol effect is somewhat lengthened if an additional quantity of the same dilute alcoholic beverage is taken after the standard dose, even though in very small additional doses (50 or 100 c. c.), and these separated by 15-minute intervals.

5. The concentration of alcohol in the urine shows an initial rapid rise, a fairly sharp maximum, and a slow decline. The alcohol effect as exhibited, for example, in station or speed of eye movement, is at first a sharp fall in efficiency. The low point in ability of performance is not maintained, but there is an irregular return in the direction of normal. Often 2 or 3 hours after the alcohol has been ingested the effect has disappeared or has been overcome. Further discussion of the relation between the intensity of the alcohol effect and the height of alcohol concentration is deferred until Chapter VII. (See p. 262.) The alcohol-urine curves from the experiments with 15-minute periods closely resemble those obtained when the urine samples are separated by 30 minutes, indicating no special advantage to be obtained from the shorter period.

6. All of the results reported in this chapter on the influence of beverages containing but 2.75 per cent ethyl alcohol by weight represent the reaction under various experimental conditions of one man who was well practiced as a subject in the neuro-muscular measurements and therefore seemed suitable for such comparative trials. Intensive many-sided results on a single normal subject may be relied upon as having a wide range of applicability.[a] Nevertheless, in the present case it seemed worth while to continue the investigation of the influence of dilute alcohol by applying a similar experimental routine to a group of men selected at random. The results from such a series of experiments are presented in the following chapter.[b]

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[a] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918.

[b] Hollingworth, Therapeutic Gazette, February 15, 1921, in brief outline, accompanied by a small table of results, reports an alcohol investigation in which he used beer containing 2.75 per cent of alcohol by weight. Six men served as subjects during a period of two weeks. Control experiments were made and preliminary periods of measurement were used for comparison with those succeeding ingestion which was on an empty stomach. From the taking of 32 to 40 grams of alcohol in this form, he found that pulse-rate increased 8 per cent, steadiness of the outstretched arm decreased 68 per cent, tapping-rate of the forearm decreased 7 per cent, and coordination in placing a stylus in small holes decreased 6 per cent. Other tests also showed decreased efficiency after the dilute alcohol. Individual differences are discussed and (personal communication) a fuller report is promised to appear in the Jour. Abnormal and Social Psychol., 1923-24. Apparently these results are in quite close agreement with our own and demonstrate definitely measurable effects following ingestion of 2.75 per cent alcohol.

CHAPTER VI.

INFLUENCE OF DILUTE ALCOHOL ON A GROUP OF YOUNG MEN.

One object of the series of experiments on a group of young men was to find if the results obtained with the trained subject, *Mow*, after the ingestion of dilute alcohol, were substantiated. The general plan of the experiments with the young men was therefore the same as in the earlier series. In the preceding chapter some attention has been given to a comparison of the intensity of the alcohol effect with the concentration of the alcohol appearing in the urine at approximately the same time. In those experiments it was assumed that the concentration of alcohol in the urine was the same as that in the blood.[a] Near the conclusion of the experiments with *Mow*, some sessions were arranged[b] in which both blood and urine samples were obtained. Analysis of these two series of samples *did not* show an identical agreement in alcohol content. Accordingly, in planning the experiments with the group, provision was made to obtain additional data on this problem. After the conditions applying to the experiments with these men have been reviewed, and before the discussion of the neuro-muscular effects of the dilute doses of alcohol, the relative content of alcohol in blood and urine samples will be considered.

EXPERIMENTAL ROUTINE AND PROGRAM.

As the experiments on this group of subjects were undertaken after several series of similar experiments had been made on the trained individual, the details of the routine had been thoroughly worked out. Furthermore, the tests employed had been in use in our psychological laboratory for a considerable period, so that technical difficulties had been largely eliminated. Each subject served 3 or 4 hours on six different days. On the first two days he was given careful instruction and systematic practice in performing the several neuro-muscular tests, the experimental program as well as the sequence of tests being the same for all of the men. Full details as to the methods of measurement are given on pages 9 to 28 in Chapter I, but a schematic outline of the program is also given here.

(1) *Patellar reflex.*—The subject reclining in a steamer chair; registration was from the thickening of the quadriceps muscle; only the amplitude of the reflex recorded; stimulus hammer of constant weight for the subject was dropped each 5 seconds for 25 times.

(2) *Skin temperature.*—Thermo-couple apparatus was used; the subject, reclining in the steamer chair, had been sitting with the backs of his hands exposed to the room air; thermo-junction readings taken from forehead, both cheeks, and two places on the back of each hand, there being in all seven skin-temperature readings.

(3) *Pulse-rate.*—Counted at the wrist; the subject continued reclining in relaxed condition. Several counts were made with a stop-watch. Much care was taken to obtain pulse counts which represented the resting state.[c]

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[a] Widmark, Upsala Läkareförenings Förhandlingar, 1914, 19, p. 241; Skand. Arch. f. Physiol., 1916, 33, p. 85. Chabanier and Ibarra-Loring, Comp. rend. Soc. biol., 1916, 79, p. 8.

[b] See table 37, experiments Nos. 68, 69, and 70, p. 131.

[c] Always in the two preliminary periods, the patellar-reflex, skin-temperature, and pulse-rate measurements were last in the order of tests; after the dose for the day they were first in each period.

(4) *Finger movement.*—The subject changed to an upright chair. Oscillations of the middle finger were recorded on a kymograph. The time was directly incorporated with the record.

(5) *Transliteration of section of Johnson's code material.*—Subject in upright chair at desk near the place of previous tests. At the exact moment of starting he uncovered 50 letters to be transliterated to the code, which was also exposed. When transliteration was completed subject called out "stop."

(6) *Continuous coordination with pursuitmeter for 5 minutes.*—The pursuitmeter was located in the room where lighting and other conditions were uniform and favorable. After a moment's practice the regular test was begun. The subject was always observed, but never interrupted. At the end of the test the meter readings were recorded, but the meters were not zeroized; later they were checked by a second reading.

(7) *Discontinuous coordination with pursuit pendulum.*—The pursuit pendulum was mounted over a sink at the end of the room near the patellar-reflex apparatus. Subject sat on a stool, so located as to give the best opportunity for a free-arm movement in the man's attempt to collect the water flowing from the pendulum during its swing of 70 cm. Each test consisted of 25 successive trials with as many different cups and required about 5 minutes. Each bank of cups was covered at the end of the trial and measurement of the amount of liquid collected was made when the test was completed.

(8) *Station.*—The man attempted to stand motionless for 2 minutes with eyes closed in a room with darkened walls and subdued light. The feet were in a prescribed position, and he stood erect with hands at sides, in approximately military position, but more comfortable and more evenly balanced. A graphic tracing of the swaying of the subject was obtained and simultaneous measurements were made by the ataxiameter of the total forward, backward, and lateral component of the swaying movement in terms of millimeters. The ataxiameter was read and recorded immediately at the end of the test.

(9) *Urine test.*—On finishing the station test, the subject passed urine directly into a graduated glass-stoppered flask. Each flask had a series number, and record was made of the collection time on both flask and protocol sheet.

This group of 9 events required 30 minutes for its completion, with a variation in length of some 3 or 4 minutes. In the first two days the purpose was to teach the subject the routine, allow him to gain some proficiency in the tests, and secure from him blood samples to be directly compared with urine samples for alcohol content. On the first day, after 1 hour's practice with the tests, the bladder was emptied, the urine being saved as a normal. Immediately afterwards, the subject drank the alcohol dose (the standard dose given to *Mow,* i. e., 27.5 grams alcohol in 1,000 c. c. of water and grape juice) at a temperature of from 18° to 19° C., and 20 minutes after the dose had been completely ingested a blood sample of 20 c. c. was taken from an arm vein in the usual manner. A needle of fairly large bore was used and a 50 c. c. syringe with exactly enough potassium oxalate in the syringe to prevent coagulation of the blood. It was usually possible to collect urine 1 or 2 minutes after the needle had been withdrawn from the vein. Blood samples were taken in this manner at intervals of 20, 40, 70, and 120 minutes; urine samples were usually passed at 22, 42, 55, 72, 87, 105, 122, 140, and 160 minutes after the complete ingestion of the alcohol dose. Each time the effort was made to empty the bladder completely. Usually the amounts of urine were large enough for purposes of analysis.

In manipulating the urine and blood samples the common precautions were taken. For the sake of clearness these may be specified.

Each urine sample was kept in the flask in which it had been collected and the quantities required for distillation were removed by a pipette. The fluid was measured for distillation at room temperature. The blood sample was in each instance forced out of the syringe into a clean and thoroughly dry bottle a little larger than necessary. This was tightly stoppered and gently shaken to insure thorough mixing with the potassium oxalate. The quantities required for distillation samples were removed from this bottle with a pipette which had previously been thoroughly rinsed with the blood sample. Particular care was taken to have the pipette empty itself very slowly, so that its sides might be cleaned in the descent of the meniscus. For the preparation of plasma samples, 14 to 15 c. c. of the whole blood, thoroughly mixed, was poured directly into a centrifuging tube. This was immediately capped and centrifuged with the cap in place to avoid any loss of alcohol by evaporation. After 10 or more minutes of centrifuging at high speed, the plasma was immediately pipetted off into a dry test-tube. This served as a receptacle for the total plasma available from the sample, the quantities required for distillation being measured off by pipettes which were likewise rinsed as before with the plasma and allowed to empty slowly. The analysis of the blood and urine samples was usually proceeding in another room while the subject was present and the experiment in progress. Of course, the blood and urine samples did not require so much time on the part of the subject who was serving in the experiment as our description may seem to indicate. He was occupied in repeatedly performing the various tests, except at the intervals when blood and urine samples were required.

On the second day that the subject came to the Laboratory, the routine of the first day was repeated and differed in only two particulars. First, as he understood what was expected from him, he could make more rapid progress and go through the series of tests a greater number of times. Second, the same amount of alcohol was given in a more concentrated form, i. e., 27.5 grams of absolute alcohol diluted to a total volume of 100 c. c. Following the ingestion of this dose, blood and urine samples were taken as before and at similar intervals, so that a direct comparison could be made not only between the alcohol concentration of the blood and urine but between the results obtained with two different dilutions of the same dose of absolute alcohol.

Blood samples were not taken on the four later days of the experimental series with each subject. These days, Nos. 3, 4, 5, and 6, were devoted to the neuro-muscular tests and the taking of urine samples every half hour following the ingestion of the alcohol. The subjects came as usual to the Laboratory, having taken certain amounts of food and liquid 3 hours or so previously and having refrained by agreement from alcohol, coffee, and tobacco. The bladder was emptied, but the urine was not saved. The routine for the day was divided into two parts, i. e., normal or preliminary periods, and those following the taking of the dose. There were two preliminary periods of measurements, the last one being followed by the passing of a urine sample which was kept as a normal urine. The dose for the day was then taken, and 5 minutes after its ingestion the tests were continued for 2 hours, that is, the series was repeated four successive times, a urine sample being taken at the end of each period. The third and sixth days of the series were control days, on which a control dose of 1,000 c. c. was given at the regular time; this was non-alcoholic, but contained the same amount of grape juice as usual. On the fourth and fifth days of the series the dose was like that given on the first day. To summarize, the routine of the 6 days was as follows:

First: Alcohol.—1,000 c. c. containing 2.75 per cent alcohol by weight, followed by collection of blood and urine samples, and practice in the neuro-muscular tests.

Second: Alcohol.—100 c. c. containing 27.5 per cent alcohol by weight, followed by collection of blood and urine samples, and practice in the neuro-muscular tests.

Third: Control.—1,000 c. c. of non-alcoholic dose, preceded by two periods of neuro-muscular tests and followed by four periods of tests. Urine samples taken.

Fourth: Alcohol.—1,000 c. c. containing 2.75 per cent alcohol by weight, preceded by two periods of testing, and followed by four periods. Urine samples taken.

Fifth: Alcohol.—1,000 c. c. of 2.75 per cent of alcohol by weight, preceded by two periods and followed by four periods. Urine samples taken.

Sixth: Control.—1,000 c. c. of non-alcoholic dose, preceded by two preliminary periods and followed by four periods of testing. Urine samples taken.

The subjects were always tested individually and in the same routine manner. The apparatus was adjusted so far as possible to meet the convenience and comfort of the individual. Before beginning the experiment, each man had been carefully instructed in reference to keeping extra-laboratory conditions constant throughout the series of experiments. No violation of these conditions came to our attention.

SUBJECTS.

Most of the subjects were medical students who had previously given blood samples for transfusion or other purposes. It seemed probable that the selection of men who had had this experience would probably result in less misunderstanding and more thorough cooperation throughout the study. The men were paid by the hour, but the amount was nominal and not sufficient to attract them unless they were otherwise interested. All who completed the series were thoroughly cooperative and reliable. Without exception, the men were in good health. Except for *Cef*, who did not finish the series, they ranged in age from 22 to 36 years. Each was seen individually some days before he came as a subject and all details were explained and agreed upon. In discussing the investigation with them at this time, special stress was laid on the problem of securing comparative results for blood and urine samples. The testing for a possible alcohol effect on neuro-muscular efficiency was only noted secondarily. Nearly all of the men had taken alcohol as a beverage at some time in their lives or were in the habit of taking it occasionally, and nearly all had experienced mild or stronger intoxication from alcohol. The general data for the various subjects are as follows:

Faf: Complete abstainer; had previously served six times as donor in blood transfusions; age, 23 years; height, 177 cm.; weight 70 kg.; perfect health.

Kom: Abstinent by habit, at present; reported previous irregular use of beer; never intoxicated; had served as donor in two blood transfusions; age, 22 years; height, 181 cm.; weight, 73 kg.; excellent health.

Hic: Usually an abstainer, but with no scruples against alcohol, having occasionally used wine; had never given blood samples; age, 24 years; height, 177 cm.; weight, 68 kg.; good health.

Jem: Recently abstinent; formerly used medium amounts of alcohol, but never much intoxicated; had previously given blood samples; age, 25 years; height, 172 cm.; weight, 63 kg.; excellent physical condition.

Sul: At times drinks a glass or two of wine and occasionally a little whisky; had been mildly intoxicated; had never given blood samples; claimed to be able to take 2 liters of liquid within a short time without discomfort; age, 29 years; height, 170 cm.; weight, 67 kg.; good health.

Rir: Recently abstinent; during 1916 and 1917 drank large amounts of light wine; had given blood for transfusion purposes; age, 33 years; height, 174 cm.; weight, 75 kg.; excellent health.

Sut: A technical student; consumes large quantities of alcohol occasionally, with reputation of being able to do so without intoxication; had tried to observe influence of alcohol on his own ability to read electrical instruments in a physical laboratory; had never given blood samples. Age, 24 years; height, 169 cm.; weight, 53 kg.; normal health.

Kac: Usually a very moderate drinker, but on two occasions had been so intoxicated that it was necessary to go to bed. Had served as subject for blood transfusion once. As he left the city before the study was ended, he was unable to complete the series of experiments. Age, 22 years; height, 175 cm.; weight, 68 kg.

Cef: Habitual user; takes alcoholic beverages of all kinds very freely and is often intoxicated. For several years was a teamster on a beer-wagon. Aside from perceptible tremor of the hands, appears to be in fairly good health. Had given small blood samples at various times. Because of breaking an ankle, was prevented from completing the series of experiments. Age, 52 years; height, 177 cm.; weight, 65 kg.

Mow: Abstinent by habit, but having served in a large number of alcohol experiments which had immediately preceded those here reported, should be classed as a moderate user of dilute alcoholic beverages; age, 36 years; height, 178 cm.; weight, 74 kg.; excellent health. Not technically a member of this group of subjects, but included in the results on the alcohol effect for purposes of averaging.

Subjects who are abstinent or moderate in their use of alcohol can be somewhat readily secured. Aside from hospital cases it is considerably more difficult to find men of the habitual or so-called "hard drinker" class who will cooperate, are trustworthy, and willing to abstain from the use of alcohol outside of the laboratory for at least a period of 24 to 36 hours prior to the experiment. In these experiments a beginning was made with three men who would qualify in this class, but the studies could not be completed with two of the men. The first (*Cef*) was rather older than desirable (52 years), but apparently in good health and a very satisfactory man to work with. The preliminary two days were carried through without difficulty, but in connection with his work outside of the Laboratory he met with an accident, breaking his ankle, and the experiments had to be discontinued. Another of these men began the first day in a very satisfactory manner, but after the taking of the first blood sample absolutely refused to proceed unless all the "blood-sample business" was omitted. He therefore left the Laboratory and nothing more could be done with him. The subject *Sut*, as noted, is a very heavy occasional drinker, and is therefore probably the nearest in the total group to the habitual type. He was a thoroughly cooperative subject, although some of the data obtained with him baffle any attempt at adequate explanation. Usually there were intervening days between experiments on any one subject; the whole series on one man was completed in something less than two weeks.

WEIGHT OF ETHYL ALCOHOL EMPLOYED.

In order that there may be no possible misunderstanding about the weight and dilution of the ethyl alcohol used, the details concerning dosage which apply to this chapter are all brought together here. All subjects received the same dose on the first, fourth, and fifth days of their individual experimental series. This was 27.5 grams of absolute alcohol, about 0.5 c. c. per kilogram of body-weight, in 300 c. c. of grape juice, the mixture being diluted with water to a total volume of 1 liter or 1,000 c. c. This had been found a convenient experimental beverage; both content and dilution are the standard adopted with the trained subject, *Mow,* as explained in Chapter V. The grape juice was of a standard commercial brand, unsweetened, and its alcohol content was frequently tested. An average of several such analyses gave 0.087 per cent alcohol by weight. The liquid, when taken, had a temperature of 18° to 20° C. In all cases, 3 to 7 minutes was a sufficient time for taking this amount of liquid (1 liter). Following the ingestion, there was usually a noticeable feeling of cold. The volume of 1,000 c. c. was not found to be excessive for any of the men.

On the second day of the experimental series with each subject, the 27.5 grams of ethyl alcohol were diluted with but 50 c. c. of grape juice and this alcohol and grape juice diluted with water to a total volume of only 100 c. c. Consequently, we have a dose of 27.5 per cent alcohol by weight. This beverage resembled a cordial. It could easily be consumed in less than 1 minute and care was taken that as little as possible was left in the glass. The control dose, given on the third and sixth days, was 300 c. c. of the grape juice diluted with water to 1,000 c. c. No other flavoring material was added.

To some extent the grape juice masked the taste of dilute alcohol; in fact, tests that were made with several of our laboratory staff as observers show that it was difficult for some individuals to tell when alcohol had been added to the grape juice in as dilute a percentage as 2.75 per cent. It is, however, quite futile to attempt to disguise the presence of alcohol in such experiments. The disguise will often be successful while the liquid is being ingested, but if the beverage has been taken on a relatively empty stomach and contains as much as 25 grams of absolute alcohol, even a moderately good observer can usually recognize the subjective effects which are and always have been a characteristic result of the ingestion of alcohol. Hallenberg[a] has shown that ethyl alcohol diluted in water to 0.01 volume per cent can be recognized as present by taste, and that smell is still more sensitive. Of course, in Hallenberg's work other flavoring materials were not present, but usually one finds, especially if the dose has been taken more than once, that after swallowing some of the liquid, subjects detect alcohol either by odor or by some action on the mucous membrane of the mouth. Invariably the men were given to understand that some alcohol was always taken. The idea of a strictly non-alcoholic control dose was never suggested to them or mentioned by any of them, and no subject knew beforehand the dosage routine of the 6 days.

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[a] Hallenberg, Skand. Arch. f. Physiol., 1914, 31, p. 75.

METHOD OF DETERMINATION OF ALCOHOL IN BLOOD AND URINE.

A modification of the Widmark-Nicloux method was used for determining the alcohol in the blood and urine. It is unnecessary to describe here with any detail the Nicloux[a] method for determining small amounts of alcohol, or the Widmark[b] modification of this method. As is well known, the reaction of alcohol with potassium-bichromate solution in the presence of sulphuric acid is the basis of the method, this being a common basis for a variety of techniques which have to do with the analysis of tissues and fluids for the presence of alcohol. As employed in our experiments,[c] we used essentially Widmark's technique, but modified it chiefly in four respects: (1) Picric acid was added to urine, plasma, and whole-blood samples, also used in making up the standard of the day; (2) the heating for distillation was milder and more prolonged, to make sure that all the alcohol in the sample should be distilled off; second distillations were made to prove that the alcohol had actually been driven over; (3) a more dilute potassium-bichromate solution was used than is recommended by Widmark; this gave greater accuracy in the determinations; (4) all samples being titrated were kept with the standard in a hot-water bath to prevent color changes due to cooling and to aid in the oxidation after successive additions of titration alcohol.

Duplicate or triplicate analyses were carried out on each sample of blood and urine, thus requiring from 30 to 40 determinations for each experiment when both blood and urine samples were taken. The method worked very satisfactorily. The procedure could be carried out rapidly and can be recommended.[d]

A large number of trial analyses were made in which alcohol was added to water, urine, or blood, but the actual amount of alcohol added was unknown to the individual making the analysis. Of 38 cases in which such trials were made with water and alcohol samples, 18 show minus results, averaging 4.4 per cent, i. e., the alcohol determined by the analytical method indicated an amount which was 4.4 per cent less than that actually known to have been added to the solution; 18 results were plus, averaging

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[a] Nicloux, Recherches expérimentales sur l'élimination de l'alcool dans l'organisme. Détermination d'une "alcoolisme congénitale." Thesis, Paris, 1900.

[b] Widmark, Skand. Arch. f. Physiol., 1918, **35**, p. 125. This author has recently described a micro-method for the determination of alcohol in blood. See Widmark, Biochem. Zeitschr., 1922, **131**, p. 473.

[c] Miles, Journ. Pharmacol. and Exp. Therapeutics, 1922, **20**, p. 265.

[d] By the Widmark technique, a standard color or sample is prepared by distilling over a certain weighed amount of alcohol into a certain amount of bichromate and sulphuric acid. As the alcohol is driven into and absorbed by the chromic acid, the color changes from yellow to yellow-green and finally to blue-green. Since the alcohol used is sufficient to reduce almost exactly the amount of potassium bichromate employed, this test-tube or a mixture of duplicates prepared the same way is used as the standard color. Then a 5 c. c. volume of solution containing an unknown amount of alcohol is distilled into a separate test-tube containing the amounts of bichromate and sulphuric acid before specified for the standard. If the unknown contains less alcohol than is contained in the standard sample, the test-tube will show a yellow-green color at the end of distillation. Alcohol is then added to the test-tube from a burette containing a solution of 5 mg. of absolute alcohol per cubic centimeter. The additions are made slowly, drop by drop, until the color exactly matches that of the standard which was produced by the known amount of alcohol. The known amount of alcohol added from the burette deducted from the amount used in preparing the standard therefore gives directly the alcohol content of the 5 c. c. of unknown solution.

4.1 per cent more alcohol than was added, and two cases happened to be exactly correct. The average for the 38 cases is therefore very close to theoretical. In 27 analyses of trial samples made up from alcohol and normal urine, 6 were minus, with an average of 2.7 per cent, and 21 plus, with an average of 3.7 per cent. With 21 samples made up from normal blood and alcohol, 18 showed minus results averaging 3.5 per cent and only 1 a plus result, which was 1.2 per cent, while 2 cases showed zero errors. If the total of 86 such trials be considered as one series, the average error is ±3.6 per cent. Nicloux,[a] in describing his original method, stated that it would give results to within 2.5 to 10 per cent, tending toward 2.5 or below after the experimenter had had much practice.

RELATION OF ALCOHOL INGESTED TO THAT APPEARING IN BLOOD AND URINE.

After a thorough test of the Widmark-Nicloux method of alcohol determination which gave assurance that the analyses were trustworthy, a number of preliminary experiments were made with one subject (*Mow*). Both blood and urine samples were obtained, the urine collection following the taking of the blood samples as quickly as possible in each case; the alcohol content of each sample was then determined and the two results compared. Several factors were varied in order to obtain information on the influence of dilution—the effect of taking plain alcohol-and-water mixtures as compared with mixtures of alcohol and grape juice; the results obtained with the subject in the post-absorptive condition as compared with those found when a small amount of food had been taken 1 hour before the alcohol; and the influence of muscular work on the alcohol content of both blood and urine.

As a result of these initial experiments, the routine previously outlined (see p. 205) was adopted and followed on the two preliminary days with the whole group of subjects. This routine limited the comparisons to the differences in alcohol content between corresponding blood and urine samples, and to the factor of dilution.

The results of the analyses of the blood samples for all of the subjects who passed through the preliminary experiments are combined in table 54. The designations of the subjects are given in the left-hand column. These are followed by the dates of the experiments, and then in four columns, headed 20, 40, 70, and 120 minutes after ingestion, are entered the average alcohol values yielded in each case by the analyses of duplicate distillations of the same blood samples. The results are stated in terms of milligrams per cubic centimeter of whole blood. The left-hand portion of the table relates to those experiments in which the alcohol was taken in 1,000 c. c. volume. The similar results when 27.5 grams of alcohol were taken in a total volume of 100 c. c. are given on the right-hand side. Thus the results for one subject are directly comparable for the two dilutions used and are shown on the same horizontal line of the table.

The first and most important point observable is that the concentration of alcohol in the blood is not uniform following the ingestion of the dose. For any and every subject when alcohol was given in a 1,000 c. c. dose, it will be observed that the concentration 20 minutes following ingestion is less than that found at 40 minutes, and this in turn is less than that existing at 70 or 120 minutes following ingestion. The concentration at 20 minutes ranges from 0.09 to 0.30 mg., with an average of 0.18 mg. per cubic centimeter. The average at 40 minutes is roughly 30 per cent higher than this, that is, 0.24. The next half hour produces about 25 per cent increase in concentration, so that at 70 minutes the values average 0.31 mg. There is apparently but little change during the next 40 or 50 minutes, for at 120 minutes the average is still 0.31 mg. per cubic centimeter. The variation between different subjects is not so great for the intervals of 70 and 120 minutes as was found 20 minutes after ingestion. The range is between 0.25 and 0.38 for the 70-minute period and between 0.24 and 0.39 for the final blood sample that was taken 2 hours after ingestion.

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[a] Nicloux, *ibid.*

TABLE 54.—*The concentration of alcohol appearing in the blood at various intervals after ingestion of alcohol in different dilutions.*

Subject.	Alcohol per c. c. of blood after 27.5 gm. alcohol in 1,000 c. c.					Alcohol per c. c. of blood after 27.5 gm. alcohol in 100 c. c.				
	Date.	20 min.	40 min.	70 min.	120 min.	Date.	20 min.	40 min.	70 min.	120 min.
	1921.	*mg.*	*mg.*	*mg.*	*mg.*	1921.	*mg.*	*mg.*	*mg.*	*mg.*
Faf........	May 20	0.22	......	0.31	0.39	June 1	0.25	......	0.37	0.32
Kom.......	May 25	.16	......	.30	.24	May 27	.29	......	.33	.28
Hic........	June 6[1]	.09	0.15	.25	.27	June 8	.36	0.46	.44	.34
Jem.......	June 13	.10	.24	.29	.35	June 14	.22	.43	.50	.39
Sul........	June 16	.20	.27	.31	.29	June 20	.39	.46	.49	.43
Rir........	July 19	.13	.22	.28	.26	July 6	.21	.36	.49	.44
Sut........	Sept. 27[1]	.12	.24	.28	.35	Sept. 30[1]	.12	.20	.31	.30
Kac........	May 31	.30	......	.36	.32	([2])	......	......	......	......
Cef........	July 13[1]	.15	.20	.38	.29	July 15[1]	.57	.54	.50	.36
Average..	....	.18	.24	.31	.31	....	.29	.43	.44	.37

[1] Results of these experiments do not appear in the averages. For the general comparison of the influence of dilution on the concentration we selected what were thought to be the six most typical experiments for each dose. *Cef* and *Sut* were habituals and between them gave disagreeing results for the 100 c. c. dose. *Hic* on June 6 was evidently in a dried-out condition, quite different from his condition on June 10 and 11. *Kac* has a strikingly high value (0.30 mg.) at 20 minutes with the 1,000 c. c. experiment. The average without this value would be 0.16 mg.

[2] Experiments had to be discontinued because subject left the city.

The changing concentration of alcohol in the blood, which is seen to be characteristic during the first hour following the 1-liter dose, is also found when the 27.5 grams of alcohol are taken in 100 c. c. The striking difference in the two sets of results is that the alcohol content in the blood is considerably higher after the more concentrated beverage has been taken.[a] At 20 minutes the range for the first six subjects is between 0.21 and 0.39 mg. This slightly overlaps the range found with the same time interval for the 1,000 c. c. dose and is on the average about 60 per cent higher. This is also characteristic of the intervals 40, 70, and 120 minutes following ingestion. Each subject shows a considerably larger amount of alcohol per cubic centimeter of blood following the taking of the more concentrated beverage and also a higher alcohol concentration in the blood 70 minutes following ingestion than is found at 120 minutes; therefore there appears to be a more definite peak in the curve when the alcohol is taken in a more concentrated form. The change between 70 and 120 minutes is on the average between 0.44 and 0.37 mgm. The variation between individual subjects is not so great with the third and fourth blood samples as with the first, which was also observed for the more dilute dose.

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[a] This result is confirmed by the new work of Hammarsten and Liljestrand (Bil. A. till Staten offentliga utredningar, 1922, 37, p. 119), who studied the alcohol content of the blood after giving doses of varying dilution and under various conditions in reference to food.

The analyses for the corresponding urine samples are shown in table 55. To give direct comparison of results, the table is limited to the analytical findings for samples taken 2 minutes after each of the corresponding blood samples, i. e., approximately 22, 42, 72, and 122 minutes following the ingestion of alcohol, the data being arranged in the same form as those for the blood samples. The general picture presented in the two tables is the same in that the alcohol content of the urine increases continuously for somewhat over an hour, and the concentration is greater when the volume of the solution in which the alcohol is taken is reduced to 100 c. c. The concentration of alcohol in the urine samples is, however, higher than that in the corresponding blood samples. A comparison of the blood and urine results obtained, respectively, 20 and 22 minutes after the ingestion of the alcohol shows the two series to be approximately alike, subject for subject. But such a direct comparison is not consistent. The taking of a blood sample requires about 30 seconds and thus the portion obtained represents simply a point on the curve of changing alcohol concentration in the blood-

TABLE 55.—*The concentration of alcohol appearing in the urine at various intervals after ingestion of alcohol in different dilutions.*

Subject.	Alcohol per c. c. of urine after 27.5 gm. alcohol in 1,000 c. c.					Alcohol per c. c. of urine after 27.5 gm. alcohol in 100 c. c.				
	Date.	22 min.	42 min.	72 min.	122 min.	Date.	22 min.	42 min.	72 min.	122 min.
	1921.	*mg.*	*mg.*	*mg.*	*mg.*	1921.	*mg.*	*mg.*	*mg.*	*mg.*
Faf........	May 20	0.15	0.48	0.52	0.43	June 1	0.20	0.52	0.52	0.42
Kom.......	May 25	.12	.29	.44	.32	May 27	.21	.52	.56	.38
Hic........	June 6[1]	.06	.13	.33	.39	June 8	.27	.61	.62	.51
Jem.......	June 13	.09	.39	.52	.52	June 14	.17	.59	.76	.57
Sul........	June 16	.24	.42	.51	.48	June 20	.52	.66	.70	.51
Rir........	July 19	.11	.27	.42	.40	July 6	.20	.35	.64	.56
Sut........	Sept. 27[1]	.12	.25	.44	.43	Sept. 30[1]	.11	.19	.41	.41
Kac.......	May 31	.26	.45	.46	.43	(2)	......	......	......	......
Cef........	July 13[1]	.11	.27	.42	.36	July 15[1]	.53	.84	.68	.44
Average..	....	.16	.38	.48	.43	....	.26	.54	.63	.50

[1] Results of these experiments do not appear in the averages. For the general comparison for dilution as it influenced concentration, we selected what were thought to be the six most typical experiments for each dose. *Sut* and *Cef* were habituals and between them gave disagreeing results, particularly for the 100 c. c. test. On June 6, *Hic* was evidently quite different (in a dried-out condition) as compared with his condition on June 10 and 11. *Kac* has a strikingly high value (0.26 mg.) at 20 minutes with the 1,000 c. c. experiment. The average without this value would be 0.14 mg.

[2] Experiments had to be discontinued because the subject left the city.

stream. The urine sample, on the contrary, represents a period of secretion of 20 or more minutes, during which the concentration of alcohol in the urine gradually changes. The urine which was first secreted during the period remained in the bladder and its low alcohol content was gradually increased by the larger amount of alcohol secreted during the latter part of the period, so that the proportion actually found in the sample taken at 22 minutes is an average value for the period of collection,[a] while the values for the blood samples represent the condition of the blood at the moment of collection.

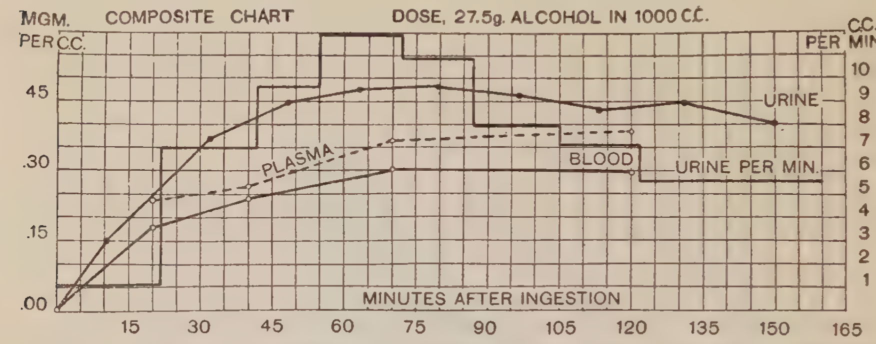

FIG. 37.—Comparative Concentration of Alcohol in Urine, Blood, and Plasma Following Ingestion of 1,000 c. c. Solution Containing 2.75 Per Cent of Alcohol.

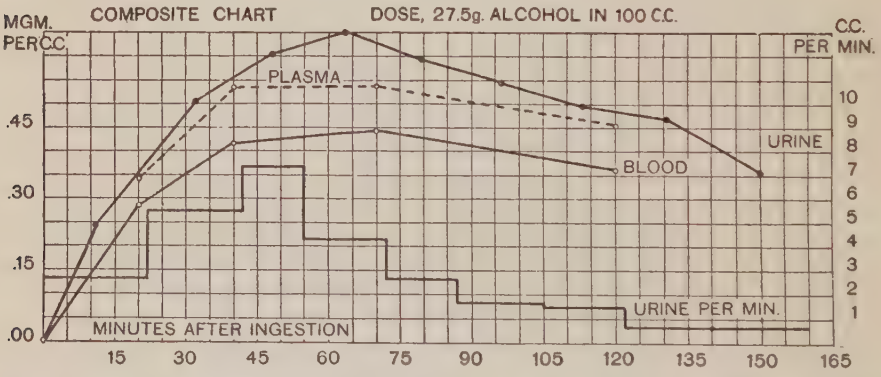

FIG. 38.—Comparative Concentration of Alcohol in Urine, Blood, and Plasma Following Ingestion of 100 c. c. Solution Containing 27.5 Per Cent of Alcohol.

The relationship between the alcohol in the urine and the blood is most simply represented by diagrams. Figures 37 and 38 have therefore been prepared to represent the data obtained in the experiments in which the volumes of the doses were 1,000 c. c. and 100 c. c., respectively, use being made of the averages in tables 54 and 55. Since, as explained above, the urine values represent averages for the period of collection, they are plotted midway in the periods, and the blood values appear at the exact time of collection. The vertical scale on the left side of the figure represents milligrams per cubic centimeter and applies equally to the three curves for the urine, blood, and plasma samples. On the abscissa is represented the time in minutes after the complete ingestion of the dose. The right-hand scale in cubic centimeters per minute refers to the curve designated as "urine per minute." In both figures this curve represents a composite of six experiments, i. e., one experiment with each of six men performed under similar conditions as to dosage, etc.

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[a] Direct tests were made of the influence of an incomplete emptying of the bladder in the collection of urine. Samples were taken at intervals of 5 or 10 minutes, the object being to retain always some urine in the bladder. The result of this retention was a very much flattened alcohol curve for the urine. (See Miles, Journ. Pharmacol. and Exp. Therapeutics, 1922, 20, p. 304, fig. 26.)

The urine curve, with the values for alcohol concentration plotted midway in the various collection periods, is constantly above the alcohol curve for the whole blood. While only a little higher in the first 20 or 30 minutes, it gradually rises 35 to 60 per cent above that for the blood. When the same weight of alcohol (27.5 grams) was taken in a more concentrated solution (a volume of 100 c. c. as compared to 1,000 c. c.), a higher alcohol concentration appears in the blood, plasma, and urine. The increase in the blood curve at the maximum point amounts to 42 per cent over that with the larger volume, while the increase in the case of the urine is 31 per cent. The alcohol concentration in the plasma is 20 to 25 per cent higher than that in the whole blood. So far as the data indicate, at the first the plasma and urine have about the same concentration for 30 or 40 minutes; later the urine is considerably higher than the plasma, which occupies an intermediate level between blood and urine.[a]

In the blood and urine the alcohol concentration appears to reach its maximum at about the same time, which is 60 to 75 minutes after ingestion. The rise before this time is quite rapid, but the maximum is rather prolonged, continuing with the dilute dose for 30 to 45 minutes. With the concentrated dose there is a sharper decline following the maximum. This decline 75 minutes after the 100 c. c. dose is also shown on the plasma curve.

RELATION OF DIURESIS TO ALCOHOL CONTENT OF URINE.

The amount of urine excreted per minute was naturally larger with the 1-liter dose. In each composite chart this block curve for urine reaches its crest about simultaneously with the urine-alcohol curve, but individual experiments, e. g., *Hic*, June 6, and *Rir*, July 5,[b] show that even contour of the urine-alcohol curve is not disturbed by rather wide changes in diuresis. But when the kidney excretion was very slight, the alcohol concentration was sometimes reduced to approximately the same level as that of the blood. The two cases in which this became evident appeared to be quite irregular and to result from a dried-out condition of the subject.

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[a] The plasma results for individual subjects have not been included in table 54, but may be found in Miles, Journ. Pharmacol. and Exp. Therapeutics, 1922, 20, p. 265, to which the reader is also directed for a comparison of our results on blood and urine with those previously given by other authors.

[b] This latter experiment has not been included in tables 54 and 55, but curves are given for it in figures 39 and 40, where, it will be observed, *Rir* appears twice. This experiment of July 5 followed a day of very strenuous physical exercise and the subject was not in a normal condition of water balance. The curves for alcohol concentration in blood and urine were closely at the same level. (See *Rir's* lower curve in the left-hand portion of both figures 39 and 40.) When the experiment was repeated under more normal conditions on July 19, the urine curve was found to be above that for blood as seen in the upper pair of curves. For a clearer contrast of the two experiments with *Rir*, see Journ. Pharmacol. and Exp. Therapeutics, 1922, 20, pp. 293 and 294, figs. 17 and 18.

The fact that the alcohol concentration in the urine, in spite of various changes in the volume of urine excreted, maintained such relationship to the alcohol concentration in the blood as is demonstrated in the composite charts, figures 37 and 38, appears to justify the use of urine samples as representative of the changes in alcohol concentration taking place subsequent to the ingestion of a dose. Both the period of rise in concentration and the time of reaching the maximum are practically identical in the two curves for blood and urine. Why the concentration in the urine should be higher than that in the blood is still to be explained. The difference in level is not, however, of such magnitude as is commonly found with other substances concentrated in the urine for excretion from the body. If ethyl alcohol were a substance commonly dealt with as is urea, then the concentration would probably be strongly affected by changes in diuresis. This we do not find to be the case, which confirms the results of certain experiments made by Widmark.[a] We are dealing here with samples of venous blood, whereas the alcohol in the urine is secured from the arterial blood. Since ethyl alcohol is a substance readily utilized, the concentration is probably somewhat higher in arterial than in venous blood. It is therefore possible, but still undemonstrated, that the alcohol in the urine may be at the same level as the concentration in the arterial blood. Should this subsequently be proved, urine samples are obviously ideal for use in alcohol experiments, particularly in those experiments designed to investigate the influence of this substance on the central nervous system. Meanwhile, and wholly as a result of the comparison given here between urine and venous blood, it would appear that the urine samples supply a satisfactory index of the changes due to the absorption and utilization of alcohol that take place subsequent to the drinking of a single portion.

Individual Differences in Alcohol Concentration in Urine.

In commenting on tables 54 and 55 attention was called to the variations between the different individuals who served as subjects. That these individual variations may be made directly more comparable and convenient for comparison, the analytical results for the left-hand portions of tables 54 and 55 have been plotted in figures 39 and 40 for blood samples and urine samples separately.

The two charts show (1) the general difference in level between the concentration of alcohol in the urine and in the blood. From them it may also be found (2) that the divergences between the subjects are approximately the same, percentagewise, for the urine as for the blood, since the urine curves are at a higher level. (3) The divergences or individual differences are most marked during the period 15 to 45 minutes after ingestion, i. e., just before the maximum alcohol concentration, and lessen thereafter. (4) With all of the nine subjects, the alcohol in the urine at the 120-minute period is somewhat lower than in the earlier periods, but this is not true for the blood alcohol, as with four subjects (*Rir, Jem, Sut,* and *Hic*) the last blood samples have the highest concentration of any examined. In the half hour after the 120-minute interval, several of the subjects show a definite drop in the urine alcohol.[a] (5) The subject, *Faf*, who had never taken alcohol before, is the one who shows the highest concentration in the urine in the early part of the experiment, but in the plotted blood results *Kac* is above *Faf*. (6) The one typical habitual drinker, *Cef* (see tables 54 and 55), and the occasional heavy drinker, *Sut*, appear to absorb and utilize the dilute alcohol in much the same way as the very moderate drinkers. (7) There is a positive correlation between the individual results for blood and urine samples, as, on the basis of general level rather than of isolated points, the subjects with high concentration in one also show it in the other. Although several of the men had given blood samples previous to engaging in these experiments, none of them had served in an experiment in which successive blood samples were desired, especially when urine samples were required as quickly as possible after the withdrawal of the needle

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[a] Widmark, Skand. Arch. f. Physiol., 1916, 33, p. 85.

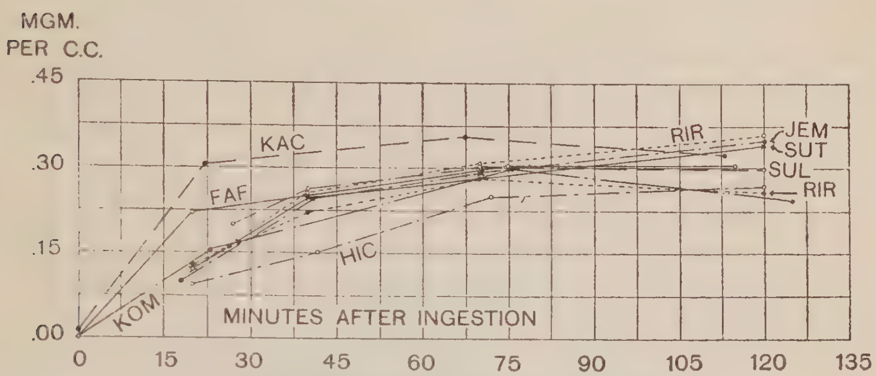

FIG. 39.—Concentrations of Alcohol in Venous Blood.

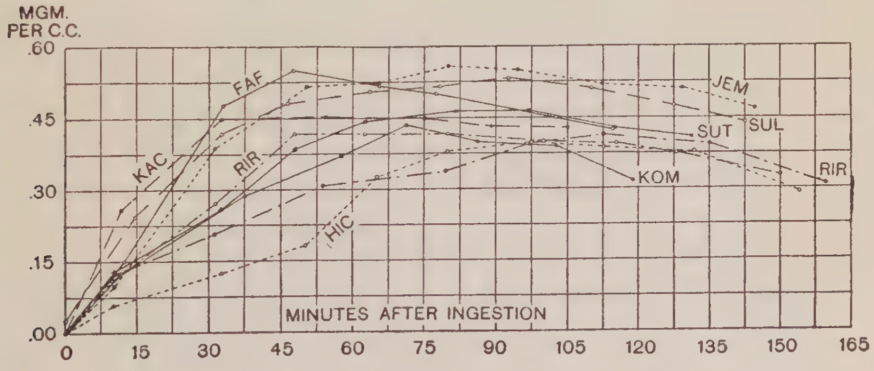

FIG. 40.—Concentrations of Alcohol in Urine.

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[a] These samples at the very end of the experiment were of course somewhat irregular. They were taken as opportunity afforded if the subject remained at the Laboratory somewhat beyond the time when the actual experiment had been finished.

from the vein. In some cases these conditions undoubtedly caused some urine retention and probably modified the results.

ALCOHOL-URINE RESULTS UNACCOMPANIED BY BLOOD TESTS.

As is indicated in the chronological outline, table 57, page 223, after the two preliminary days each subject served on two days when a dose with a

TABLE 56.—*The concentration of alcohol appearing in the urine at intervals after the ingestion of 27.5 grams of alcohol in 1 liter of beverage.*

Subject.	Date.	Alcohol experiments.							Control experiments.	
		Alcohol per c. c. of urine after—				Total urine ex-creted.	Total alcohol ex-creted.	Propor-tion of alcohol ex-creted.	Date.	Total urine ex-creted.
		35 min.	65 min.	95 min.	125 min.					
	1921.	*mg.*	*mg.*	*mg.*	*mg.*	*c. c.*	*mg.*	*p. ct.*	1921.	*c. c.*
Faf......	June 29	0.36	0.52	0.47	0.38	1,038	463	1.7	June 28	728
	June 30	.43	.59	.49	.39	1,021	503	1.8	July 1	917
	Avg.	.40	.56	.48	.39	1,030	483	1.8		823
Kom.....	June 2	.15	.37	.42	.36	797	300	1.1	May 28	428
	June 3	.19	.43	.43	.35	988	396	1.4	June 4	496
	Avg.	.17	.40	.43	.36	893	348	1.3		462
Hic......	June 10	.29	.44	.44	.41	1,124	468	1.7	June 9	944
	June 11	.26	.46	.46	.39	1,114	463	1.7	June 13	1,105
	Avg.	.28	.45	.45	.40	1,119	466	1.7		1,025
Jem.....	June 16	.24	.43	.54	.54	696	324	1.2	June 15	705
	June 17	.24	.48	.53	.51	669	328	1.2	June 18	580
	Avg.	.24	.46	.54	.53	683	326	1.2		643
Sul......	June 29	.25	.44	.47	.42	1,042	429	1.6	June 27	939
	June 30	.23	.44	.48	.42	1,036	436	1.6	July 1	1,004
	Avg.	.24	.44	.48	.42	1,039	433	1.6		972
Rir......	July 8	.17	.39	.40	.35	496	183	.7	July 7	478
	July 11	.14	.35	.41	.42	574	214	.8	July 14	487
	Avg.	.16	.37	.41	.39	535	199	.8		483
Sut......	Oct. 14	.28	.69	.69	.64	761	500	1.8	Oct. 10	859
	Oct. 20	.36	.53	.47	.41	851	388	1.4	Oct. 21	897
	Avg.	.32	.61	.58	.53	806	444	1.6		878
	1920.								1920.	
Mow.....	Dec. 9	.21	.43	.41	.39	810	373	1.4	Dec. 8	834
	Dec. 10	.22	.44	.43	.40	1,047	519	1.9	Dec. 11	832
	Avg.	.22	.44	.42	.40	929	446	1.6		833
	Gen. avg.	.25	.46	.47	.42	879	393	1.4		766

volume of 1,000 c. c. was consumed which contained 27.5 grams of alcohol, and on two other days when the same volume of non-alcoholic beverage was consumed. In these later experiments only urine samples were taken, and these at 30-minute intervals; therefore the bladder was each time more satisfactorily emptied than in the earlier experiments when the period of secretion was shorter. The subject urinated at the beginning of the experiment. At the end of preliminary period 2 the bladder was again emptied, this urine on the alcohol days being taken as the normal. Urine samples were then invariably taken on the four days at 35, 65, 95, and 125 minutes after complete ingestion of the 1,000 c. c. dose. The general data for each subject and for the individual experimental days are gathered together in table 56. While urine samples were taken in the control experiments, they were not analyzed, and only the total volumes of urine excreted within the 2 hours following the control dose are here recorded. These data are given in the right-hand section of the table, together with the dates of the experiments. In the left-hand portion of the table, the alcohol content of the various urine samples is recorded for the respective intervals following the ingestion of the alcohol. Each record in terms of milligrams per cubic centimeter of urine is an average of two or more analyses of the same urine sample. The total volume of urine is given, also the total number of milligrams of alcohol excreted in this volume of urine, and finally, the percentage of the ingested alcohol (27.5 grams) which was excreted through the urine in the 2 hours during which the experiment continued after the drinking of the alcohol dose. The 8 men show averages of 0.25, 0.46, 0.47, and 0.42 mg. per cubic centimeter at the various intervals of 35, 65, 95, and

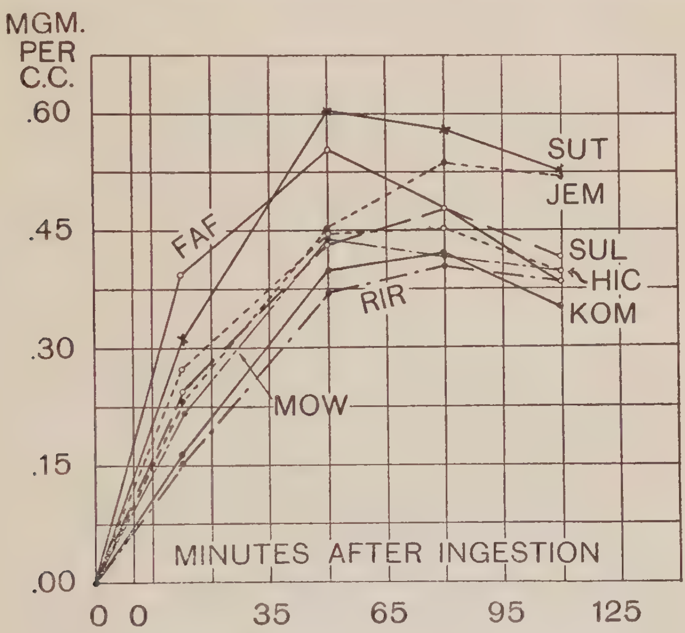

FIG. 41.—Concentrations of Alcohol in Urine in Later Tests.

125 minutes following drinking. If these average values be plotted midway for the periods of urinary secretion which they individually represent, it will be observed that the curve so resulting would almost superimpose on the urine-alcohol curve given in figure 37 for the earlier observations, when both blood and urine samples were taken.

When the results for the subjects are compared, the individual differences are clear, as was likewise found in the curves for the earlier observations grouped in figure 40. These differences may be studied conveniently in figure 41. The scale for time on the abscissa is somewhat condensed in this figure in comparison with that in figure 40. As previously found, the curves for *Faf* and *Jem* indicate a higher alcohol concentration and those for *Kom* and *Rir* a lower concentration than the average. These individual differences will be discussed later in connection with the numerical statement for the effect of alcohol as shown by the various neuro-muscular tests on the different men. The point to be emphasized here is that the results for urine alcohol found with samples taken at intervals of 30 minutes closely agree with results obtained at shorter intervals and when the urine samples were taken in connection with venous-blood samples. In later charts showing the influence of alcohol on the various neuro-muscular measurements, the average results for urine alcohol of the 8 men in table 56 have been plotted for general comparison with the intensity and time relations of the alcohol effect.

URINARY OUTPUT AFTER DILUTE ALCOHOL.

On the average the total amount of urine excreted in the 2 hours which comprise the four experimental periods following the dose was 879 c. c. The total amount of alcohol that escaped utilization in this period by way of excretion through the urine averaged 393 mg. of the 27.5 grams ingested, or a little more than 1.4 per cent. With ten preliminary experiments in which both blood and urine samples were collected and a dose of 1,000 c. c. containing 2.75 per cent alcohol was taken by the subject, the total urine excretion averaged 669 c. c. and the alcohol excretion averaged 286 mgm., or approximately 1.0 per cent. The earlier average was, however, considerably influenced by two experiments in which the urine volume was very small, this being in both cases less than 230 c. c. with an alcohol excretion well below 0.5 per cent, whereas in the later experiments given in table 56 the alcohol excreted ranged from 0.7 to 1.9 per cent.

The problem of alcohol elimination through the urine has been discussed by a number of writers.[a] If the elimination found with our experiments within 2 hours is somewhat greater than others have recorded, the conditions of dosage and sampling may possibly account for this discrepancy. We have used a relatively small amount of alcohol in dilute form and without food. The diuresis was comparatively large, there was only a moderate amount of physical exercise, and the urinations were so frequent that the opportunity was relatively slight for the alcohol to be reabsorbed from the bladder into the blood-stream. It is improbable that the individual differences in alcohol effect on various subjects can be credited to the differences in alcohol elimination shown by the various men. At least, the urinary elimination is too small an amount of the total to be considered as a factor in our experimental results with dilute beverages.

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[a] **Miles, Journ. Pharmacol. and Exp. Therapeutics, 1922, 20, p. 305.**

From the Volhard[a] test for kidney efficiency, it has been found that healthy individuals usually excrete within 2 hours more than half of the liquid ingested. In our experiments, the average volume of liquid following the non-alcohol dose was 766 c. c. for a 2-hour period, with a range in the 16 control experiments from 428 to 1,105 c. c. of urine. Pairs of experiments on the same subject agree well as to the amount of urine eliminated. For example, *Kom,* whose excretion on May 28 (428 c. c.) was smallest in amount of any of the subjects, had in his other normal experiment a total excretion of 496 c. c., while *Hic,* with 1,105 c. c. on June 13, gave 944 c. c. on June 9. The average volume of 879 c. c. following the alcohol dose is about 15 per cent larger than that found when the dose did not contain alcohol, and may possibly be considered as a diuretic effect of the alcohol. When the 16 pairs of alcohol and control experiments on the horizontal lines in table 56 are compared directly, 12 indicate a larger total urinary volume following the alcohol experiments. *Sut,* the occasional heavy drinker, is an exception in both pairs of experiments, and *Jem* and *Mow* each show in the first pair slightly larger volumes following control solutions. However, *Mow,* with whom many series of individual experiments were made, characteristically gives the same effect of alcohol on the urinary excretion as is demonstrated for the group as an average. (See table 52, p. 175.)

Rosenfeld,[b] in a summary of the literature up to 1901, appears to show that especially dilute alcoholic solutions exercise a diuretic influence. Januszkiewicz,[c] in experiments with such solutions, found increases of from 25 to 40 per cent in the volume of urine excreted during the 6-hour period. There are objections, at least theoretically good, to comparing beer or ale with water and assuming that the increased diuresis is due only to the ethyl alcohol. Very probably other constituents in these common alcoholic beverages may be of influence in this connection. In the experiments we are reporting here, the ingested solutions were identical in volume and in constituents with the exception that one contained 27.5 grams of alcohol. The diuresis is supposedly due to an increased and early absorption of water along with the alcohol. No discussion was ever indulged in with any of the subjects as to the possibility of an increased diuresis following the alcohol and no subject, at least at the Laboratory, ever mentioned the matter. It was a wholly secondary consideration in planning and carrying out the experiments, but since the volume of the ingesta, the time relations, number of urine samples, and the insistence upon complete emptying of the bladder were the same throughout, the trustworthiness of the results may perhaps be even greater than if obtained for the direct purpose of testing the question of diuresis.[d]

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[a] Volhard, Handbuch d. inn. Medizin, 1918, **3**, part 2, p. 1197.

[b] Rosenfeld, Einfluss des Alkohols auf den Organismus. Wiesbaden, 1901.

[c] Januszkiewicz, Zeitschr. f. Biol., 1911, **56**, p. 401.

[d] In the typewriting series discussed in Chapter II, in which the total volumes of both the control and the alcohol doses were always small (200 c. c. or less), the protocols show that in several of the alcohol experiments the subjects had to be excused for urination about an hour after the dose, but this was never necessary in the control experiments.

Conclusions Regarding Concentration of Alcohol in Blood and Urine.

Before presenting the results for the influence of dilute alcohol on the neuro-muscular efficiency, our conclusions from comparisons of the alcohol concentration in blood and urine may be stated as follows:

(1) The alcohol concentration in venous blood and urine after taking 27.5 grams of absolute alcohol diluted to 1,000 c. c. or 100 c. c. is not identical in the first 2 hours after ingestion. The alcohol content of the urine is invariably higher than that of the blood, even from the beginning. From 40 minutes to 2 hours after ingestion this greater concentration in the urine is approximately 40 to 50 per cent higher than that for the whole blood and 20 to 25 per cent higher than that for the plasma.

(2) When the same weight of alcohol is taken in two widely differing concentrations (2.75 and 27.5 per cent), the more concentrated beverage produces definitely a higher concentration in both blood and urine than is found with the dilute beverage.

(3) Different subjects vary considerably in the concentration of alcohol appearing in the body fluids following the same dose, but if the concentration is high in the blood, it is found to be high in the urine also.

(4) The content of alcohol in the urine is not particularly influenced by the amount of urine excreted; therefore the process seems to be one of diffusion rather than that of concentration of alcohol for excretion.

(5) The fact that the alcohol content of the urine is not the same as that of the venous blood, but 40 to 50 per cent higher, leads to the question still unanswered as to whether the urine content may not reflect the alcohol content of the arterial blood, in which case urine samples would apparently be ideal for comparison with the numerical sequence of alcohol effect on the central nervous system.

(6) While the alcohol concentration in the urine is not identical with that of the blood, still the time relations of the two curves show marked similarity in period of rise, time of maximum, and, to a less extent, in the beginning of fall. This being true, the urine-alcohol curve may be usefully compared with objective measurements of the alcohol effect, with some possibility of correlation of the intensity of the alcohol effect with the height of concentration and of the increase and decrease of the effect with the increase and decrease of the alcohol concentration.

(7) The urine alcohol results also indicate that the excretion of unused alcohol through the urine is not sufficient to account for individual differences in the effect of alcohol upon the subject, since in all cases the amount thus excreted within 2 hours after ingestion is somewhat less than 2 per cent of that which has been ingested. The volume of urine after dilute alcohol is found to be increased.

INFLUENCE OF DILUTE ALCOHOL ON NEURO-MUSCULAR EFFICIENCY OF A GROUP OF EIGHT MEN.

The general chronology of the experiments with the various subjects, the time of day when the experiment began and ended, the amount of time elapsing between the last food ingested and the taking of the alcoholic or the control beverage, also the samples collected—either blood and urine or urine only—are shown in table 57. The total volume of the dose and the

TABLE 57.—*The chronology and general data for the experiments with dilute alcohol on a group of young men subjects.*

Subject.	Date.	Type of experiment.	Experiment began.	Experiment ended.	Time between dose and last food.[1]	Samples for analysis.[2]	Total volume of dose.[3]	Concentration of alcohol by weight.[4]
	1921.		*p. m.*	*p. m.*	*hrs.*		*c. c.*	*p. ct.*
Faf.......	May 20	Alcohol[5]	$1^{h}45^{m}$	$4^{h}50^{m}$	6¾	Blood and urine.	1,000	2.75
	June 1	...Do.[5]..	1 45	4 05	6	......Do.......	100	27.5
	June 28	Control.	1 00	4 03	6½	Urine..........	1,000	....
	June 29	Alcohol.	1 00	4 18	6½	..Do...........	1,000	2.75
	June 30	...Do...	1 00	4 15	6½	..Do...........	1,000	2.75
	July 1	Control.	1 05	4 20	6½	..Do...........	1,000	....
Kom......	May 25	Alcohol[5]	1 00	4 18	6	Blood and urine.	1,000	2.75
	May 27	...Do.[5]..	1 00	4 50	6	......Do.......	100	27.5
	May 28	Control.	12 40	3 45	6	Urine..........	1,000	....
	June 2	Alcohol.	12 45	4 00	3¾	..Do...........	1,000	2.75
	June 3	...Do...	12 40	3 45	4	..Do...........	1,000	2.75
	June 4	Control.	12 30	3 45	6	..Do...........	1,000	....
Kac[6]......	May 31	Alcohol[5]	1 00	4 16	6	Blood and urine.	1,000	2.75
Hic.......	June 6	Alcohol[5]	12 50	5 10	6¼	Blood and urine.	1,000	2.75
	June 8	...Do.[5]..	1 00	4 03	5¾	......Do.......	100	27.5
	June 9	Control.	1 00	4 15	6	Urine..........	1,000	....
	June 10	Alcohol.	1 00	4 15	6	..Do...........	1,000	2.75
	June 11	...Do...	1 00	4 15	6	..Do...........	1,000	2.75
	June 13	Control.	1 00	4 45	6	..Do...........	1,000	....
			a. m.					
Jem......	June 13	Alcohol[5]	$8^{h}30^{m}$	12 05	[7]10	Blood and urine.	1,000	2.75
			p. m.					
	June 14	...Do.[5]..	$12^{h}40^{m}$	4 00	5	......Do.......	100	27.5
	June 15	Control.	1 00	4 15	5½	Urine..........	1,000	....
	June 16	Alcohol.	1 00	4 35	4½	..Do...........	1,000	2.75
	June 17	...Do...	1 00	4 30	4¾	..Do...........	1,000	2.75
	June 18	Control.	12 00	3 25	[7]18	..Do...........	1,000	....
			a. m.					
Sul.......	June 16	Alcohol[5]	$8^{h}30^{m}$	12 10	[7]14¼	Blood and urine.	1,000	2.75
	June 20	...Do.[5]..	9 10	12 41	[7]15½	......Do.......	100	27.5
				a. m.				
	June 27	Control.	8 45	$11^{h}55^{m}$	[7]15	Urine..........	1,000	....
	June 29	Alcohol.	8 35	11 50	[7]15	Do...........	1,000	2.75
	June 30	...Do...	8 35	11 59	[7]15	..Do...........	1,000	2 75
	July 1	Control.	8 30	11 50	[7]15	..Do...........	1,000	....
			p. m.	*p. m.*				
Rir.......	July 5[8]	Alcohol[5]	$1^{h}00^{m}$	$4^{h}50^{m}$	6½	Blood and urine.	1,000	2.75
	July 6	...Do.[5]..	1 00	4 23	6	......Do.......	100	27.5
	July 7	Control.	1 00	4 00	6½	Urine..........	1,000	....
	July 8	Alcohol.	1 05	4 00	6½	..Do...........	1,000	2.75
	July 11	...Do...	1 00	4 00	6½	..Do...........	1,000	2.75
	July 14	Control.	1 00	4 30	6½	..Do...........	1,000	....
	July 19[8]	Alcohol.	1 05	4 30	6¼	Blood and urine.	1,000	2.75
Cef.......	July 13	Alcohol[5]	1 00	5 20	6¼	Blood and urine.	1,000	2.75
	July 15[9]	...Do.[5]..	1 00	5 00	5¾	......Do.......	100	27.5
Sut.......	Sept. 27	Alcohol[5]	2 30	5 50	2¾	Blood and urine.	1,000	2.75
	Sept. 30	...Do.[5]..	1 40	4 56	2	......Do.......	100	27.5
	Oct. 10	Control.	3 15	6 15	3¾	Urine..........	1,000	....
	Oct. 14	Alcohol.	3 15	6 25	3¾	..Do...........	1,000	2.75
	Oct. 18	...Do...	3 15	6 30	3¾	..Do...........	1,000	2.75
	Oct. 21	Control.	3 00	5 58	3	..Do...........	1,000	....

For explanation of reference marks, see footnotes on following page.

TABLE 57.—*The chronology and general data for the experiments with dilute alcohol on a group of young men subjects*—Continued.

Subject.	Date.	Type of experiment.	Experiment began.	Experiment ended.	Time between dose and last food.[1]	Samples for analysis.[2]	Total volume of dose.[3]	Concentration of alcohol by weight.[4]
	1920.		*p. m.*	*p. m.*	*hrs.*		*c. c*	*p. ct.*
Mow......	Dec. 8	Control.	1 00	4 15	2	Urine..........	1,000	....
	Dec. 9	Alcohol.	1 00	4 15	2	..Do...........	1,000	2.75
	Dec. 10	...Do...	1 00	4 15	2	..Do...........	1,000	2.75
	Dec. 11	Control.	1 00	4 15	2	..Do...........	1,000	....

[1] Food taken before coming to the Laboratory.

[2] Blood samples from an arm-vein were taken 20, 40, 70, and 120 minutes following ingestion of dose. A urine sample was obtained within 2 minutes after the taking of a blood sample, and other urine samples were interspersed.

[3] The 1,000 c. c. dose always contained 300 c. c. of grape juice, to which, on alcohol days, 37 c. c. of our ethyl-alcohol solution (91.28 per cent by weight) were added and this diluted with water to a total volume of 1 liter. The 100 c. c. dose contained 50 c. c. grape juice, 37 c. c. of alcohol solution and water. The amount of alcohol was thus the same with both volumes.

[4] The amount of alcohol in the dose on alcohol days, regardless of concentration, was always 27.5 grams.

[5] Except with *Mow*, the first and second experiments with each man were to provide preliminary practice in the psychological measurements and an opportunity to compare the alcohol concentration of blood and urine samples.

[6] *Kac* had to leave the city following the experiment and the series could not be continued.

[7] Subject came in post-absorptive condition, i. e., with no food since the night before.

[8] On July 4, *Rir* engaged in a large amount of physical exercise, therefore the experiment of July 5 was repeated on July 19.

[9] *Cef* broke his ankle on July 16 and the series of experiments could not be continued.

percentage of alcohol by weight are likewise included in this table; the weight of alcohol in the dose was invariably 27.5 grams. Two of the subjects for whom data are given in the table (*Kac* and *Cef*) were not able to complete the series. Except in the experiments with *Sul*, the observations were always made in the afternoon, and quite uniformly covered a little more than 3 hours. The amount of time which elapsed between the previous food and the taking of the dose was never less than 2 hours. In *Mow's* case the food was uniform and consisted of four small crackers, with a small portion of conserve on each. One subject, *Sul*, came to the Laboratory in the post-absorptive condition. Likewise, in the last experiment with *Jem* (the control experiment on June 18), the subject was in the post-absorptive condition. This, while undesirable, was necessary to accommodate other plans made by the subject.

The routine previously discussed of collecting samples of both blood and urine on the first two days is clearly indicated in the table. As already brought out, these days were preliminary and for practice purposes only so far as the neuro-muscular tests were concerned. Their results are therefore not included in the grouping of the data in subsequent tables.

Regardless of some variance in body-weight, the men received the same alcohol dosage, both as to the weight of absolute ethyl alcohol employed and the total volume to which it was diluted. The amount of alcohol given and the particular dilution used were fixed upon rather arbitrarily after the many preliminary experiments on *Mow*. The weight of alcohol (invariably 27.5 grams) was well within what has been commonly considered a moderate dose and was 10 per cent larger than the small dose used by Dodge and Benedict.[a] The volume selected (1 liter), although fairly large, can usually be taken easily within 10 or 15 minutes by any man of usual adult size.

The program of neuro-muscular tests has been outlined and the various techniques briefly described in the fore part of this chapter (p. 204); more detailed descriptions are given in Chapter I, particularly for some of the techniques. We may therefore proceed directly to a consideration of the alcohol results for the different measurements.

PULSE-RATE.

In the two initial periods of each day, the three measurements, patellar reflex, skin temperature, and pulse-rate, were taken at the end of the period. This appeared to be a more favorable time to secure the necessary relaxation than the beginning of the period, as was the routine after the dose was taken. (See p. 204.) The diluted alcohol or the control dose was therefore given immediately after the recording of the pulse-rate in period 2, except that the subject urinated before he drank the beverage. Following the ingestion of the liquid, the subject sat down in the steamer chair and remained quiet for 5 minutes. Then the third period was begun with measurements of the patellar reflex, the skin temperature, and the pulse-rate. At the end of period 6, after urinating, the subject again returned to the steamer chair and sat quietly for some time before additional and final observations were made of both the skin temperature and the pulse-rate.

The pulse data, as given in terms of pulse-rate per minute (see p. 10 for the technique), are presented in table 58. As previously explained, the routine with each subject was the same (see p. 204); therefore the results of the two alcohol days have been averaged for each subject for comparison with the average results of the two control or normal days for the same subject. Table 58, whose arrangement is typical of the tables which follow, is divided into sections according to the captions in the left-hand column of "Control," "Alcohol," and "Effect of alcohol." In the section designated as "Control," the average data for each individual for the two days with the non-alcoholic dose have been given by periods. For example, in the case of *Faf*, under preliminary 1, the value 65.2 is an average of results obtained in the first period on both normal days. Since on each day there were three or more counts in each period, this figure represents an average of at least six pulse-counts taken at the end of the first preliminary period. Likewise, 64.5 entered under preliminary 2 is an average representing counts taken on both days at the end of period 2, and just prior to the drinking of the non-alcoholic control dose. The position of the dose is indicated by the double line. The four pulse-rates, 62.5, 61.3, 62.9, and 66.3, which are entered respectively under columns 3, 4, 5, and 6 in the same line, are all averages for the two control days, and each observation was made near the beginning of the period which it represents. The additional pulse-count which was taken following period 6 is entered in the column headed 7, and is also an average for both days at this point. Finally, in the column headed "Average after dose," we find 63.4, which is the average of the five values which succeed the taking of the control dose. In the alcohol section of the table there is a similar line of averages for *Faf*. The first two averages, of course, represent normal conditions, as they were preliminary to the taking of the alcohol. In each case the counts were made at the end of the respective periods. Following the alcohol, the pulse-counts were made near the beginning of the period except for the last count, an average of 65.7, which was made at the end of the experimental session.

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 30.

TABLE 58.—*The pulse-rate of a group of 7 men as influenced by the ingestion of 1,000 c. c. of 2.75 per cent alcohol.*

Subject, and type of experiment.	Pulse-rate per minute at successive half-hour periods.							Average after dose.
	Preliminary.		Following dose.					
	1	2	3	4	5	6	7	
Control:								
Faf	65.2	64.5	62.5	61.3	62.9	66.3	64.2	63.4
Kom	76.3	73.0	64.8	66.6	70.3	73.6	71.8	69.4
Hic	65.8	63.1	61.1	61.5	66.7	61.5	60.3	62.2
Jem	62.2	60.1	57.4	57.7	57.6	58.8	57.2	57.7
Sul	74.4	72.9	72.8	75.0	74.4	76.2	71.0	73.9
Rir	60.0	62.9	56.2	60.0	62.0	58.9	58.9	59.2
Sut	76.1	74.8	63.7	64.7	68.2	71.1	64.9	66.5
Averages	68.6	67.3	62.6	63.8	66.0	66.6	64.0	64.6
Differences	(68.0)		− 5.4	− 4.2	− 2.0	− 1.4	− 4.0	− 3.4
Alcohol:								
Faf	63.2	62.0	63.2	65.5	64.0	68.0	65.7	65.3
Kom	76.8	73.0	69.8	75.8	74.2	74.5	75.0	73.8
Hic	57.9	58.3	61.0	64.9	72.3	69.0	66.3	66.7
Jem	60.9	62.3	58.6	65.3	67.0	66.5	66.6	64.8
Sul	70.1	71.4	74.5	77.3	77.0	75.6	72.4	75.3
Rir	57.4	58.0	54.5	57.6	58.1	60.1	59.9	58.0
Sut	74.7	71.1	63.0	75.3	78.1	72.3	71.0	71.9
Averages	65.9	65.2	63.5	68.8	70.1	69.4	68.1	68.0
Differences	(65.6)		− 2.1	+ 3.2	+ 4.5	+ 3.8	+ 2.5	+ 2.4
Effect of alcohol:								
Differences for group			+ 3.3	+ 7.4	+ 6.5	+ 5.2	+ 6.5	+ 5.8
Per cent for group	(66.8)		+ 4.9	+11.1	+ 9.7	+ 7.8	+ 9.7	+ 8.6
Per cent for individuals								
Faf			+ 4.7	+10.2	+ 5.3	+ 6.3	+ 6.0	+ 6.5
Kom			+ 6.4	+12.0	+ 4.9	+ 0.9	+ 4.0	+ 5.6
Hic			+10.3	+16.0	+19.6	+22.7	+20.2	+17.8
Jem			+ 1.3	+11.7	+14.7	+11.9	+14.7	+10.9
Sul			+ 6.4	+ 7.2	+ 7.6	+ 3.2	+ 5.9	+ 6.1
Rir			+ 3.5	+ 2.3	− 0.2	+ 8.4	+ 8.0	+ 4.4
Sut			+ 2.6	+17.8	+16.8	+ 5.1	+11.7	+10.8
Average per cent			+ 5.0	+11.0	+ 9.8	+ 8.3	+10.1	+ 8.8

The alcohol effect has been computed by the method of differences, as was done for *Mow* in Chapter V. (See p. 46.) The use of two preliminary periods instead of one has been adopted throughout this later series with dilute alcohol in the belief that an average of these two periods in each case would probably more nearly satisfy our object of securing a reliable normal of the day in the case of each measurement. Therefore, throughout the discussion of these data, the results are presented only by the method of differences.

Since each subject contributes to table 58 the same amount of data, and the time relations, the total length of the experiment, and the dosage were also very closely the same with all of the men, the whole group of results may be averaged. Thus, for the control preliminary 1, the average for the 7 subjects shows a pulse-rate of 68.6 beats, while the average for preliminary 2 is slightly less (67.3 beats per minute). Following the taking of the control dose, the rate falls at first somewhat more than 4 beats per minute, that is, to an average level of 62.6 beats. This definite fall is indicated with every subject except *Sul*, whose pulse-rate changed only from 72.9 to 72.8. In periods 4, 5, and 6 the pulse gradually increases from the low level found after the cool liquid was ingested, the average rates for these periods being 63.8, 66.0, and 66.6. The average pulse-rate did not return to the level of the preliminary periods, even though the pulse-rate was taken at the ends of the preliminary periods, that is, after the subject had been quiet for a considerable time and not at the very beginning of the experiment. The average for the final pulse-count is 64.0 beats. This average decrease of 2.6 beats per minute between the beginning and end of period 6 is probably because of the relatively greater relaxation which came at the end of the experiment, since the subject had nothing more to do but to sit in the steamer chair. He was sometimes allowed to sit quietly several minutes before the pulse counts were made. This decrease in pulse-rate between the beginning and end of period 6 (see records in columns 6 and 7) is evident with all of the subjects except *Rir*. The average for all counts following the control dose is 64.6 beats per minute.

For the preliminary or normal value we use the average of the pulse-rates for periods 1 and 2, i. e., 68.0 beats. In comparison with this, the averages recorded in columns 3 to 7 indicate differences from normal of −5.4, −4.2, −2.0, −1.4, and −4.0, respectively, the average difference being −3.4 beats. The records following the control dose were characterized by a decrease in the rate. This was most pronounced immediately after the taking of the liter of liquid (5.4 beats), and gradually changed until the pulse-rate was but 1.4 beats slower than the preliminary pulse-rate, although the very last record was 4 beats slower.

On the 14 days which we have designated as alcohol days, the preliminary average pulse-rate for the 7 subjects in period 1 was 65.9 beats per minute, while for period 2 it was 65.2, the average normal rate in these preliminary periods therefore being 65.6 beats. This pulse-rate is 2.4 beats per minute slower than the average rate found in the preliminary periods of the 14 non-alcohol days. After the taking of the beverage containing 2.75 per cent of alcohol, the average pulse-rate dropped to 63.5, which is only 2.1 beats per minute less than the preliminary average. There was a quick recovery, with the result that for the last four counts we find values of 68.8, 70.1, 69.4, and 68.1 beats. The average pulse-rate for the periods following the alcohol dose was 68.0 beats per minute. If these various averages are compared directly with those which were obtained after the taking of the control dose, it will be found in each case that the pulse-rates obtained after alcohol are higher. The contrast is even more pronounced if the levels in the preliminary periods for the two groups of days are taken into account. The differences between the average preliminary and the pulse-rates after the dose on the alcohol days are in order of periods −2.1, +3.2, +4.5, +3.8, and +2.5, with an average for all differences after the alcohol of +2.4 beats.

The effect of the alcohol is represented by the area between the two groups of differences. This quantity is obtained by subtracting the differences with the control dose from the differences with the alcohol dose which results in the following differences for the effect of alcohol, all with the same sign: +3.3, +7.4, +6.5, +5.2, +6.5, with an average of +5.8 beats per minute. That the effect of alcohol on the pulse-rate may be compared directly with its effect upon other measures, these differences are converted into terms of per cent, using as a basis the preliminary average rate obtained on the control days (68.0) and that on the alcohol days (65.6), thus obtaining the general average of 66.8 beats per minute. The results for the various counts following the taking of alcohol, which we have numbered 3 to 7 in the table, show the effect of alcohol in increasing the pulse-rate to be, stated in per cent, as follows: +4.9, +11.1, +9.7, +7.8, and +9.7, with an average of +8.6.

In the lower portion of the table the percentage effect is given for the individual subjects, computed in the same way as those for the whole group. Since the preliminary values for each individual have, of course, been used in computing his percentage effect, the average of the individual results for the whole group will not exactly correspond with the average obtained by combining all the original data in one series. The most striking feature here is the preponderance of plus signs. There is, in fact, only one minus sign, that for *Rir* in period 5 of −0.2. Therefore, as indeed the right-hand column of averages following the dose clearly shows, with all 7 subjects the pulse-rate increased following the alcohol. The average change ranges from +4.4 per cent for *Rir* to +17.8 per cent with *Hic*. Three of the men show effects larger than 10 per cent, while the general average for all is +8.8 per cent. The individuality of the subjects is quite consistent throughout all of the periods; for example, *Hic*, whose average effect of alcohol is the largest, likewise indicates a large effect in all of the periods, these being, in sequence, 10.3, 16.0, 19.6, 22.7, and 20.2 per cent. The maximum occurred at the beginning of the sixth period, as was also the case with *Rir*. Three subjects show the maximum effect at the beginning of the fourth period and two others at the beginning of the fifth, but when all are averaged, the predominant effect appears to be at the beginning of period 4, with +11 per cent, which decreases to +9.8, and +8.3 in periods 5 and 6.

As a means of visualizing these data for pulse-rate in a simple manner for comparison with the data for concentration of alcohol in the urine, the chart in figure 42 has been prepared. This chart is typical of those which will follow. The urine curve represents the average results which were found for all of the subjects used. These individual results have been presented in table 56 (see p. 218) and show 0.25, 0.46, 0.47, and 0.42 mg. of alcohol per cubic centimeter of urine at 35, 65, 95, and 125 minutes after the ingestion of the alcohol. These values have been plotted in figure 42, in each case at a point half way in the period represented by the collection of the urine sample. By means of a light line and open dots, the curve for alcohol concentration in the blood has also been plotted for the two preliminary days on which the blood samples were taken. (See table 54, p. 212.) The scale at the left of the chart designated "mg. per c. c." refers to the urine and blood curves. On the abscissa are represented the time before the ingestion of the dose began and after the ingestion was finished, allowing 10 minutes for the drinking of the liter of liquid. The scale at the extreme left of the figure applies to the curves representing the group averages for the control and alcohol days, while the scale at the right refers to the curve for the percentage effect of alcohol on pulse-rate. The averages for the control days (i. e., those days with the non-alcoholic dose) are indicated by a broken-line curve, with open dots. The corresponding averages for the alcohol days are shown in a solid-line curve with open dots.

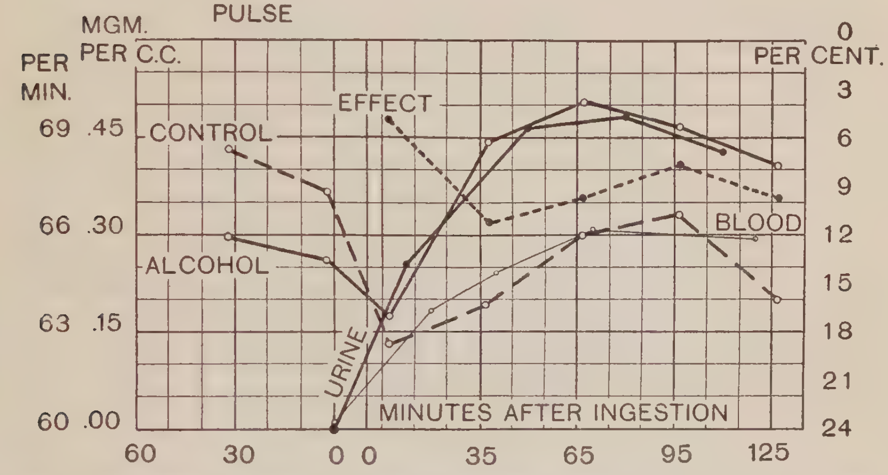

FIG. 42.—Average Pulse-rate of 7 Men Following Ingestion of Very Dilute Alcohol (27.5 Grams in Volume of 1,000 c. c.).

The contrast between the two series of averages for pulse-rate per minute is well brought out in the figure. Notwithstanding that the preliminary level for control days is somewhat higher than that on the alcohol days, the pulse-rates following the non-alcoholic dose are in all cases definitely lower than those following the alcohol dose, so that, wholly disregarding any preliminary values, it is clearly to be seen that the pulse-rate is faster following the alcohol. If the preliminary values are also considered, we obtain the curve designated "Effect," with the scale at the right side of the figure. In this scale the zero is at the top and the divisions indicate plus percentages, that is, increased pulse-rate in terms of per cent. The maximum effect of the alcohol on the pulse-rate as obtained from the average results is found to occur 40 to 70 minutes following ingestion, when the urine and blood curves likewise indicate that the concentration of the alcohol was reaching its maximum. There was relatively little change following this point for the rest of the experimental session, the alcohol effect remaining approximately at 9 per cent.

These data for the effect of dilute alcohol on the pulse-rate are very consistent for all the subjects. They agree essentially with the results which were obtained in our typewriting experiments and in the series using rectal injection of alcohol during sleep. Furthermore, they substantiate the earlier results obtained in this Laboratory by Dodge and Benedict.[a] These authors pointed out that there is a gradual slowing of the pulse-rate during a 3-hour experimental session and the alcohol effect which they observed was largely in the nature of a simple cancellation of this progressive slowing of the pulse-rate. Something of this may be observed in connection with the typewriting experiments. In experiments in which a liter of cool fluid is ingested at one time, a definite change is produced in the pulse-rate during the 30 minutes following. From this definite change there is a gradual recovery in the direction of an increase which appears to continue for an hour or an hour and a half. Apparently, however, the alcohol effect is present to some extent very soon after the ingestion of the complete amount. The pulse-record was taken at the beginning of period 3, i. e., approximately 20 minutes following ingestion. Although there is some drop in pulse-rate due to the liter of fluid, there is still clear evidence that the level is above that found after the control dose and the increase in pulse-rate between periods 3 and 4 is larger after alcohol than following the control dose. Taken as a whole, these data show a more pronounced increase in pulse-rate as an alcohol effect than any which have previously been published from the Nutrition Laboratory. The alcohol not only counteracted the progressive slowing of the pulse-rate during the experimental period, but actually increased the rate above that found in the preliminary periods before the taking of the dose, so that the effect of quickened pulse-rate due to alcohol is absolute as well as relative.

When the results are summarized for the effect of dilute alcohol on the pulse-rate in this series of experiments, it is found:

(1) After the ingestion of 1 liter of non-alcoholic liquid taken at a temperature of 18° to 19° C., there is a definite drop in the pulse-rate within the following hour, amounting to about 5 beats per minute; thereafter the pulse gradually increases in rate, but does not fully return to the original level indicated by the records taken before the dose.

(2) Following the taking of 27.5 grams of ethyl alcohol diluted to a volume of 1,000 c. c., with a temperature of 18° to 19° C., there is some drop in pulse-rate, but not so much as when the liquid is non-alcoholic. Subsequently there is a quick return to a level equal to or surpassing that found before the alcohol was taken, so that the pulse-rate is absolutely as well as relatively increased after the ingestion of alcohol.

(3) Seven male subjects show increases in pulse-rates associated with the taking of alcohol, which amount to from 4.4 to 17.8 per cent, with an average of 8.8 per cent for the period of 2 hours following the ingestion of the alcohol. The maximum effect is from 40 to 70 minutes after ingestion and is somewhat over 10 per cent. Our pulse counts were not taken under so-called "basal conditions," for the subjects sat in a steamer chair and had been mildly active 10 minutes before the counting.

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 186.

(4) The occurrence of the maximum effect of the alcohol on the pulse-rate appears fairly synchronous with the highest concentration of alcohol in the urine.

SKIN TEMPERATURE.

Seven skin-temperature readings were made in each experimental period, three on the face and in two positions on the back of each hand. One reading was made at each position. The points used were closely the same but were not marked. Only very light pressure was used in applying the junction to the skin. The apparatus and technique are described on page 11.

The three readings taken on the face were averaged together and, following the method of treatment used for the pulse-rate data, the two normal days have been averaged for each subject, period by period; likewise the two alcohol days. In table 59, which is the same in form as that giving the

TABLE 59.—*Skin temperature of the face at various intervals after the ingestion of 27.5 grams of alcohol diluted to volume of 1,000 c. c.*

Subject and type of experiment.	Temperature of face at successive half-hour periods.							Average after dose.
	Preliminary.		Following dose.					
	1	2	3	4	5	6	7	
Control:	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
Faf	33.23	33.27	32.88	32.68	33.07	33.46	33.14	33.05
Kom	34.18	33.82	33.73	34.08	34.39	34.48	34.26	34.19
Hic	34.01	34.21	34.06	33.94	34.37	34.38	34.51	34.25
Jem	33.14	33.11	33.09	32.82	32.88	32.98	33.10	32.97
Sul	33.16	33.87	33.85	33.73	33.93	34.09	33.97	33.91
Rir	34.14	34.07	34.11	34.33	34.19	34.30	34.47	34.28
Sut	33.30	33.62	33.10	33.63	32.88	32.76	32.82	33.04
Average	**33.59**	**33.71**	**33.55**	**33.46**	**33.67**	**33.78**	**33.75**	**33.64**
Differences	(33.65)		**−0.10**	**−0.19**	**+0.02**	**+0.13**	**+0.10**	**−0.01**
Alcohol:								
Faf	32.90	32.85	32.70	32.88	33.32	33.17	33.10	33.03
Kom	34.24	33.66	33.98	34.43	34.54	34.57	34.24	34.35
Hic	34.27	34.69	34.45	34.56	34.81	34.95	34.70	34.69
Jem	32.85	32.95	32.93	33.09	33.30	33.70	33.61	33.33
Sul	33.48	33.87	33.54	33.84	33.72	33.61	33.59	33.66
Rir	33.47	33.17	33.59	33.51	33.80	33.76	33.50	33.63
Sut	34.02	33.75	32.93	33.29	33.73	33.57	33.54	33.41
Averages	**33.60**	**33.56**	**33.45**	**33.66**	**33.89**	**33.90**	**33.75**	**33.73**
Differences	(33.58)		**−0.13**	**+0.08**	**+0.31**	**+0.32**	**+0.17**	**+0.15**
Effect of alcohol:								
Differences for group	......	......	**−0.03**	**+0.27**	**+0.29**	**+0.19**	**+0.07**	**+0.16**
Per cent for group[1]	(33.62)		**−0.1**	**+0.8**	**+0.9**	**+0.6**	**+0.2**	**+0.5**
Per cent for individuals[1]								
Faf	......	......	+0.6	+1.7	+1.9	+0.2	+1.0	+1.1
Kom	......	......	+0.9	+1.2	+0.6	+0.4	+0.1	+0.6
Hic	......	......	+0.1	+0.7	+0.2	+0.6	−0.5	+0.2
Jem	......	......	+0.2	+1.5	+2.0	+2.9	+2.2	+1.8
Sul	......	......	−1.4	−0.2	−1.1	−1.9	−1.6	−1.2
Rir	......	......	+0.8	−0.1	+1.2	+0.7	−0.5	+0.4
Sut	......	......	−1.8	+0.7	+1.3	+1.1	+0.9	+0.4
Average per cent	......	......	**−0.1**	**+0.8**	**+0.9**	**+0.6**	**+0.2**	**+0.5**

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[1] The alcohol effect in terms of per cent is given for skin temperature as it has been for the other measurements. It is recognized, however, that percentage change from the average temperature as a base is not an ideal means of stating the alcohol effect in this case.

results for pulse-rate, each of the 7 subjects is represented in all three sections of the tables by one horizontal line of values giving the average temperature of the face. As would be expected, the temperatures range closely between 33° and 34° C. Similar values were found in connection with a previous study of undernutrition.[a] The average for the first preliminary period for the control day is 33.59° C., with a range between 33.14° C. and 34.18° C., that is, a little over 1° C. For the second preliminary period, the average of 33.71° C. is slightly above that for the first. Following the ingestion of the liter of non-alcoholic solution, which was taken at a temperature of 18° to 19° C., 6 of the 7 men show a decrease in skin temperature of the face. The average, 33.55° C., is 0.16° C. below the average for preliminary period 2. The average for period 4 is still lower than that for period 3, but following this the temperature rose and the last three averages closely approximate those obtained in preliminary period 2. The average for the five sets of observations following the dose of control solution is 33.64° C. as compared with an average of 33.65° C. for the two preliminary periods.

The preliminary averages for alcohol days are 33.60° and 33.56° C. for periods 1 and 2, with an average of 33.58 ° C. Following the ingestion of the liter of liquid containing 2.75 per cent of alcohol, there is first a drop of 0.13° C. from the average preliminary temperature, but from period 4 onward the temperatures are absolutely higher than those found in the preliminary periods. The effect of alcohol, computed in terms of degrees in temperature change (see "Differences for group," in table 59) is −0.03, +0.27, +0.29, +0.19, and +0.07° C. for observations 3 to 7, respectively.

The results presented for the effect of alcohol in terms of per cent (a faulty method in the case of skin temperature) are fairly homogeneous[b] for the different individuals. The plus sign, indicating increase in skin temperature, decidedly predominates. One subject, however, *Sul*, consistently shows a lower skin temperature after the alcohol, this decrease amounting on the average to −1.2 per cent. With the other subjects, the observations after the alcohol show an increase in temperature on the average, ranging from 0.2 to 1.8 per cent. The average for the individuals was the same as that for the group, i. e., +0.5 per cent.

The group results in table 59 for the skin temperature of the face are charted in figure 43, together with the curves for alcohol concentration in the urine and the curve for alcohol concentration in the blood. The skin temperature of the face, irrespective of preliminary levels for control and alcohol days, was higher after the ingestion of the alcohol than after the control mixture, the curve showing the maximum change at the place corresponding in time to the maximum concentration of alcohol in the urine.

In appraising this alcohol effect, the usual marked stability and narrow range of normal fluctuation in temperature should receive attention. In terms of degrees, the alcohol produced a maximum increase of 0.29° C. and an average increase of 0.16° C. The extreme range shown by table 43 appears to be represented by *Faf,* in period 4 (control 32.68° C.) and *Hic,* in period 6 (alcohol 34.95° C.). This is a difference of 2.27° C. If this difference or temperature range is used as a base for figuring a percentage alcohol effect, then the maximum increase in period 5 would equal about 13 per cent and the average an increase of near 7 per cent in the skin temperature of the face.

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[a] Benedict, Miles, Roth, and Smith, Carnegie Inst. Wash. Pub. No. 280, 1919, p. 250, table 23.

[b] Here we are measuring a physiological process on a physical scale, the zero of which is quite unrelated to the process measured. Had our temperature readings been taken in degrees Fahrenheit, the percentage alcohol effect would obviously have been smaller than it is on the centigrade scale.

The skin-temperature observations for both hands have been averaged and recorded in table 60. Each entry for an individual subject represents the average of two observations on the right hand and two on the left hand on two comparable experimental days, or the average of eight temperature readings. The results presented in table 60 and in figure 44 show preliminary temperatures for the hands which are approximately 1° C. less than those for the face in corresponding periods. There is a definite drop in the temperature between the two preliminary periods on both control and alcohol days, the only exception being the results for *Hic* in both the control and the alcohol tests and those for *Rir* in the alcohol tests. The drinking of the liquid causes a further fall in temperature, except for a slight rise in the alcohol tests with *Kom.* Beyond this, the temperature for the control days remains fairly constant at about 1° C. lower than the average preliminary. On the alcohol days, however, the temperature recovers from the fall immediately succeeding the ingestion of the liquid, and during the period from 65 to 95 minutes after the taking of the alcohol maintains a higher level than that of the average preliminary. The temperature of the hands 35 to 125 minutes after the alcohol is likewise higher absolutely than the temperature following the control solution.

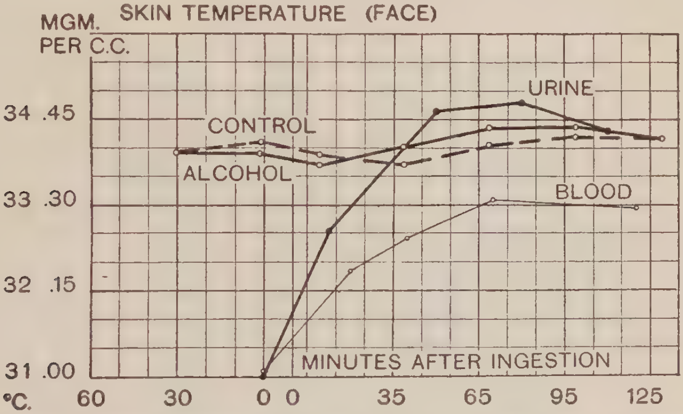

FIG. 43.—Average Skin Temperature (Face) of 7 Men Following Ingestion of 27.5 Grams of Alcohol in 1,000 c. c. Solution.

The "effect" curve for per cent has been omitted from this chart.

In terms of degrees, the alcohol effect on the skin temperature of the hands from the average of observations made after the dose is +0.73° C. (equivalent to 2.2 per cent for the group). The curves indicate that the maximal influence of the alcohol on the skin temperature of the hands corresponds closely to the period of maximal concentration in the urine and is roughly four times as large as that shown for the temperature of the face. But it will be appreciated that the skin temperature of the hands is more variable than that of the face. One subject, *Sut*, indicated a consistent and comparatively very large negative effect. As the skin temperature of his hands seems to have been abnormally low, his results have not been averaged in the group. Five of the subjects (see lower portion of table 60) show by the plus signs consistent increases in skin temperature of the hands following alcohol.[a]

TABLE 60.—*Skin temperature of the hands at various intervals after the ingestion of 27.5 grams of alcohol diluted to volume of 1,000 c. c.*

Subject and type of experiment.	Temperature of hands at successive half-hour periods.							Average after dose.
	Preliminary.		Following dose.					
	1	2	3	4	5	6	7	
Control:	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
Faf	32.42	32.03	30.99	29.99	29.42	29.28	29.42	29.82
Kom	34.50	32.99	32.06	32.98	33.19	33.17	32.48	32.78
Hic	32.31	32.41	31.75	32.23	33.51	33.12	33.21	32.76
Jem	32.49	31.24	30.51	29.12	29.11	28.74	28.87	29.27
Sul	32.31	31.97	31.53	31.23	31.82	32.16	32.26	31.80
Rir	34.58	34.41	33.19	34.43	34.11	34.16	33.92	33.96
Sut[1]	30.56	28.53	28.14	26.35	25.62	25.03	24.92	26.01
Averages	**33.10**	**32.51**	**31.67**	**31.66**	**31.86**	**31.77**	**31.69**	**31.73**
Differences	(32.81)		**−1.14**	**−1.15**	**−0.95**	**−1.04**	**−1.12**	**−1.08**
Alcohol:								
Faf	32.59	32.08	30.56	30.49	30.37	30.29	29.66	30.27
Kom	34.04	31.94	32.01	33.37	34.12	33.72	32.27	33.10
Hic	33.02	33.53	32.68	33.94	34.99	34.36	34.15	34.02
Jem	32.22	30.73	30.19	28.99	30.58	31.48	31.10	30.47
Sul	33.10	32.32	31.64	32.13	32.75	32.12	31.65	32.06
Rir	31.59	32.55	31.86	32.76	33.51	33.40	32.89	32.88
Sut[1]	34.23	32.83	29.80	27.73	28.09	27.39	26.69	27.94
Averages	**32.76**	**32.19**	**31.49**	**31.95**	**32.72**	**32.56**	**31.95**	**32.13**
Differences	(32.48)		**−0.99**	**−0.53**	**+0.24**	**+0.08**	**−0.53**	**−0.35**
Effect of alcohol:								
Differences for group	....	....	+0.15	+0.62	+1.19	+1.12	+0.59	+0.73
Per cent for group[2]	(32.65)		+0.5	+1.9	+3.6	+3.4	+1.8	+2.2
Per cent for individuals[2]								
Faf	....	....	−1.7	+1.2	+2.6	+2.8	+4.0	+1.8
Kom	....	....	+2.1	+3.5	+5.1	+3.9	+1.7	+3.3
Hic	....	....	±0.0	+2.4	+1.7	+1.0	+0.1	+1.0
Jem	....	....	+0.2	+0.8	+5.9	+9.9	+8.3	+5.0
Sul	....	....	−1.4	+1.0	+1.1	−1.9	−3.6	−1.0
Rir	....	....	+3.3	+2.3	+5.5	+5.0	+4.2	+4.1
Sut[1]	....	....	−7.4	−8.2	−4.8	−5.1	−7.0	−6.5
Average per cent	....	....	+0.4	+1.9	+3.7	+3.5	+2.5	+2.4

[1] The data for *Sut* are in this case not included in the averages.

[2] The alcohol effect in terms of per cent is given for skin temperature as it has been for the other measurements. It is recognized, however, that percentage change from the average temperature as a base is not an ideal means of stating the alcohol effect in this case.

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[a] von Wendt, Skand. Arch. f. Physiol., 1907, 19, p. 171, found a maximum rise of about 0.5° C. The effect was, however, of briefer duration than in our experiments. Probably von Wendt used a concentrated alcohol dose. The amount was 42 grams.

The effects of alcohol upon the skin temperature may be summarized as follows:

(1) Associated with the ingestion of 1 liter of non-alcoholic liquid at a temperature of 18° to 19° C., there is a fall in the skin temperature of both hands and face, which is considerably more marked in the hands.

(2) Within 2 hours the skin temperature of the face recovers to approximately the preliminary level, but that of the hands does not.

(3) Following ingestion of 1 liter of solution containing 27.5 grams of alcohol, the recovery of the skin temperature from the fall is much more rapid than with the non-alcoholic dose. Both face and hands may reach the preliminary temperature level. The maximum effect of the ingestion of alcohol is an increase of about 0.3° C. in the temperature of the face and 1.2° C. in the temperature of the hands. The average effect for the 2 hours after ingestion amounts, respectively, to 0.16° and 0.73° C.

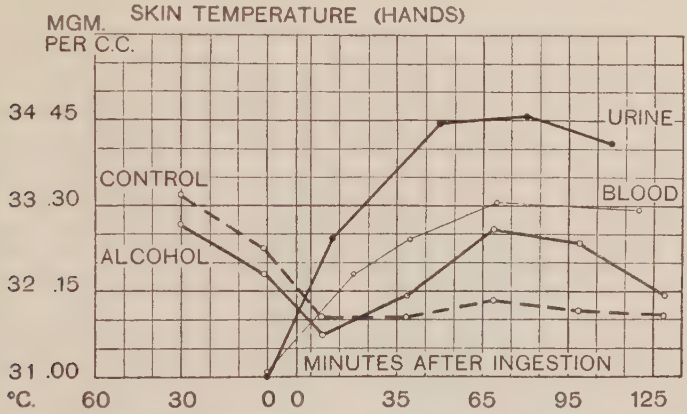

Fig. 44.—Average Skin Temperature (Hands) of 7 Men Following Ingestion of 27.5 Grams of Alcohol in 1,000 c. c. Solution.

The "effect" curve for per cent has been omitted from this chart.

(4) The change produced by alcohol on the skin temperature gradually increases as the concentration of alcohol increases in the urine, and reaches its maximum at or about the same time; subsequently it diminishes while the concentration is also diminishing slightly in the urine.

(5) The consistent alcohol effect on the skin temperature demonstrated by the large majority of these men is thought to be important evidence for the physiological influence of dilute alcoholic beverages when considered in relation to the very limited range of temperature change which is normal.

Patellar Reflex.

The stimulus intensity for each subject was the same throughout his series of tests. Only the reflex amplitude was measured. The latency is not an independent feature of the reflex, but is related to the amplitude of contraction.[a] Its short duration makes it difficult to measure with exactitude. We have therefore omitted consideration of it here and rested the discussion entirely on the size of the reflex contraction. The kymograph paper moved at the slow rate of 0.5 mm. per second, hence the muscle contractions which, by the lever system, were magnified six times, appear as sharp spikes, the length of which can be accurately determined.

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[a] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 43.

As is well known, the reflex amplitude for the knee-jerk varies with different subjects through a wide range. The data presented in table 61, which, in this case, represents averages of approximately 50 reflexes, show variations in the muscle thickening for the different men from 1 to 24 mm. Three subjects, *Jem*, *Rir*, and *Sut*, commonly exhibited very slight reflexes, sometimes averaging less than 1 mm. in amplitude, notwithstanding the fact that the recording mechanism magnifies sixfold. The results for these three subjects do not appear in the averages in table 61. One subject, *Hic*, was completely refractory, so that no records could be obtained with him.

TABLE 61.—*The amplitude of the patellar reflex following the ingestion of 27.5 grams of alcohol diluted to volume of 1,000 c. c.*

Subject and type of experiment.	Amplitude of patellar reflex at half-hour periods.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Control:	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Faf	3.8	4.2	6.4	5.6	5.3	5.6	5.7
Kom	13.5	12.4	10.8	10.5	11.7	10.3	10.8
Jem[1]	2.4	2.2	8.8	3.3	3.2	2.6	4.5
Sul	10.8	11.5	24.3	12.3	12.0	10.4	14.8
Rir[1]	1.3	1.9	5.1	1.6	1.1	0.5	2.1
Sut[1]	0.8	0.5	4.6	2.0	1.3	0.4	2.1
Averages[1]	9.4	9.4	13.8	9.5	9.7	8.8	10.5
Differences	(9.4)		+ 4.4	+ 0.1	+ 0.3	− 0.6	+ 1.1
Alcohol:							
Faf	5.4	4.5	6.3	4.5	4.8	6.7	5.6
Kom	15.6	14.6	14.6	9.4	8.6	10.4	10.8
Jem[1]	3.3	1.0	2.9	0.8	0.5	0.8	1.3
Sul	11.7	10.2	20.0	6.2	11.4	9.8	11.9
Rir[1]	3.3	1.5	5.1	0.6	0.4	0.8	1.7
Sut[1]	0.3	0.1	2.7	0.2	0.1	0.1	0.8
Averages[1]	10.9	9.8	13.6	6.7	8.3	9.0	9.4
Differences	(10.4)		+ 3.2	− 3.7	− 2.1	− 1.4	− 1.0
Effect of alcohol:							
Differences for group			− 1.2	− 3.8	− 2.4	− 0.8	− 2.1
Per cent for group	(9.9)		− 12	− 38	− 24	− 8	− 21
Per cent for individuals:							
Faf			− 24	− 47	− 33	+ 2	− 26
Kom			+ 12	− 23	− 37	−14	− 16
Jem[1]			−252	−104	−113	−74	−136
Sul			− 37	− 53	− 4	− 4	− 25
Rir[1]			− 40	− 90	− 75	−25	− 58
Sut[1]			−280	−260	−140	+40	−160
Average per cent[1]			− 16	− 41	− 25	− 5	− 22

[1] Subjects *Jem*, *Rir*, and *Sut* gave such small reflexes that an average has been made without them.

Reference to the percentage effects for the individual subjects given in the lower part of table 61 shows clearly that the minus sign or a decrease in reflex amplitude following alcohol strongly predominates. There are only three cases in which a subject shows a slight increase in reflex amplitude for some one period. The three men, *Jem*, *Rir*, and *Sut*, who exhibit very slight normal reflexes, are naturally the ones who show percentagewise the most marked effect from the alcohol, their averages being −136, −58, and −160 per cent, respectively. In the case of the patellar reflex amplitude we have a measurement which in variability is quite in contrast to that of skin temperature.

The average effect of alcohol exhibited by *Faf*, *Kom*, and *Sul*, all of whom regularly had fairly normal reflexes and were the only men included in the general averages, is represented for the various periods following the dose by percentage changes of −12, −38, −24, and −8 per cent, respectively, with an average decrease for observations following alcohol of −21 per cent. These results are exhibited in graphic form in figure 45. There is a prominent increase in the amplitude of the reflex following the ingestion of the liter of liquid, regardless of whether the solution given was control or alcohol. This increase amounts to 3 or 4 mm. on a base of 10 mm. It is very probably associated with the cooling of the body due to the ingestion of the liquid, as such increases in reflex amplitude have been observed by us in connection with exposure of the body to cold air.[a] The effect is transitory, as can be seen from the curves. After the control solution, the reflex amplitude returns in period 4 to the preliminary level, and is constant thereafter. After the alcohol solution, however, the reflex amplitude in period 4 has not returned to the preliminary level, but has sunk conspicuously below it, this resulting in a marked drop in the curve showing the alcohol effect. The maximal effect is synchronous with the maximum concentration cf alcohol in the urine and by the close of the experiment it has so decreased that the alcohol effect is then only 8 per cent instead of the 38 per cent found in the fourth period. The results for all six subjects (see table 61) bear out the observations that the alcohol effect on the amplitude of the patellar reflex occurs chiefly in the first hour following its ingestion. *Jem* and *Sut*, who exhibit the most pronounced alcohol effect,

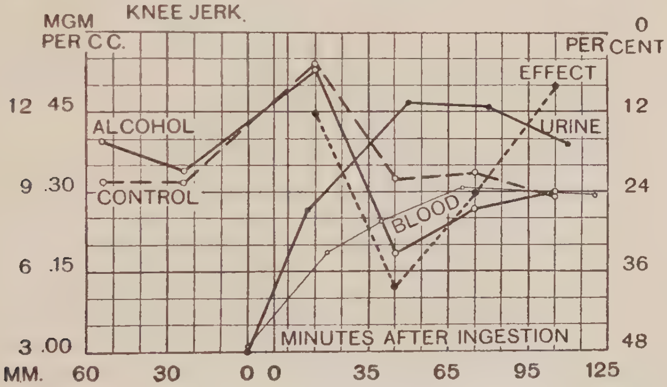

Fig. 45.—Average Effect of Very Dilute Alcohol on the Patellar Reflex.

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[a] Unpublished material.

probably because their normal reflexes were very small, show the maximal effect occurring in the first reflexes taken following ingestion, which, in this case, would not be more than 10 minutes removed from the completion of drinking the dose.

From these results the following conclusions may be drawn as to the effect of alcohol on the patellar reflex.

(1) The amplitudes of the patellar reflex varied widely for the different subjects used in our experiments, and any consideration of the rather marked alcohol effect should take into account the usual variability of this measure.

(2) The ingestion of a liter of liquid at 18° to 19° C. is accompanied by a large increase in the amplitude of the patellar reflex. This increase is less when the liquid contains alcohol.

(3) Following the alcohol, the amplitude of the patellar reflex decreases to a level considerably below that shown following the control mixture and below that exhibited in the preliminary for the day. Thus the alcohol effect is pronounced, amounting at its maximum, which corresponds or slightly precedes in time the maximal concentration of the blood, to 38 per cent. Similarly a large percentage effect for alcohol on the patellar reflex was observed by Dodge and Benedict[a] and also by Miles,[b] in earlier work published from the Nutrition Laboratory.

STATIC EQUILIBRIUM.

The test for station is the first one in our series which is definitely modified by practice. During the two preliminary days the subjects were tested in this as in the other measurements and showed considerable improvement. Any changes due to improvement were, however, minimized in influence by the arrangement of the experimental program. As the results of the first two preliminary days were entirely discarded, the initial practice changes were completely eliminated. Furthermore, of the other four days, the first and last were controls.

AMOUNT OF SWAY.

In the data which are presented in table 62, the range between subjects for the amount of linear swaying movement is not so great as with some measurements. In the first preliminary period for control days, the results ranged from 792 to 535 mm., with an average of 630 mm. The reader will bear in mind that the larger the score, the poorer is the performance in this case, since the score represents in millimeters the total for the anterior-posterior and lateral components of all the swaying movements made during a period of 2 minutes while the subject is standing with eyes closed. There is relatively little change in the average from period to period on the control days, as can readily be seen in figure 46, the average score remaining close to 650 mm., with an average for the four periods following the ingestion of the control solution of 653 mm. All of the periods following the control dose show averages a little higher, i. e., 3 to 22 mm., than the average for the two preliminary periods, 637 mm. This change does not seem to be progressive, as might be expected if due to increasing fatigue.

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 54.

[b] Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 48.

The preliminary level for alcohol days closely approximates that on control days, differing by only 6 mm. Following the ingestion of the alcohol, there is a marked increase in swaying, this amounting, on the average, in the first measurement, to 71 mm. more than the increase after the control dose. As this measurement of station came at the end of the period, it was the farthest removed from the dose, the first station test following alcohol being about 35 minutes after ingestion. For period 4, that is, 30 minutes later, the effect is still more marked, showing an increase of 129 mm. over the normal. The effect becomes less pronounced in period 5, but

TABLE 62.—*Influence of dilute alcohol on static equilibrium of eight men after ingestion of 27.5 grams of alcohol diluted to 1,000 c. c.*

(Amount of sway.)

Subject and type of experiment.	Total linear movement tested at successive half-hour periods.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Control:	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Faf	792	894	873	896	697	775	810
Kom	615	616	618	493	537	572	555
Hic	624	648	713	740	753	788	748
Jem	535	520	526	552	608	535	555
Sul	568	580	592	608	634	617	613
Rir	749	795	852	848	732	742	794
Sut	612	656	565	612	640	661	619
Mow	548	435	534	517	515	548	528
Averages	**630**	**643**	**659**	**658**	**640**	**655**	**653**
Differences	(637)		+22	+21	+ 3	+18	+16
Alcohol:							
Faf	646	812	1,120	1,313	1,156	921	1,127
Kom	638	640	670	640	676	563	637
Hic	657	641	766	806	803	672	762
Jem	564	476	489	549	536	514	522
Sul	606	609	590	703	582	574	612
Rir	823	716	890	911	747	730	819
Sut	616	605	727	660	615	636	659
Mow	526	512	538	662	602	563	591
Averages	**635**	**626**	**724**	**781**	**715**	**647**	**717**
Differences	(631)		+93	+150	+84	+16	+86
Effect of alcohol:							
Differences for group			+71	+129	+81	−2	+70
Per cent for group	(634)		+11.2	+ 20.4	+12.8	−0.3	+11.0
Per cent for individuals:							
Faf			+45.9	+ 67.6	+72.9	+33.1	+54.9
Kom			+ 4.6	+ 19.8	+18.5	− 5.1	+ 9.6
Hic			+ 6.2	+ 8.2	+ 5.8	−20.1	± 0.0
Jem			− 5.5	+ 1.0	−12.2	− 2.5	− 4.8
Sul			− 6.1	+ 10.3	−14.6	−13.0	− 5.9
Rir			+ 5.2	+ 8.4	+ 2.2	− 1.3	+ 3.6
Sut			+29.7	+ 11.4	− 0.3	− 0.3	+10.1
Mow			− 4.5	+ 23.3	+11.9	− 2.4	+ 7.1
Average per cent			+ 9.4	+ 18.8	+10.5	− 1.5	+ 9.3

it is still larger than in period 3, while in period 6 the subjects did as well following the alcohol as they did following the control dose. In figure 46 the curve for the effect of alcohol shows values for periods following the dose of +11.2, +20.4, +12.8, and −0.3 per cent, respectively. The average for the four periods is an increase in swaying of 11 per cent. The maximal effect of the alcohol on this measure corresponds to the time when the alcohol is at its highest concentration in the urine, but it is clear that the effect on static equilibrium decreases much more rapidly than the alcohol concentration decreases.

If the individual results for the 8 subjects are noted (see lower portion of table 62), it will be seen that with 5 of the men there is an increased sway 35 minutes after the alcohol is taken, while all of the men show increases varying from 1 to 68 per cent at the end of the fourth period, approximately 65 minutes after the alcohol. For the fifth period, there are again 5 who still show an increased swaying, but in the sixth period, 7 exhibit less swaying after the alcohol than after the control dose

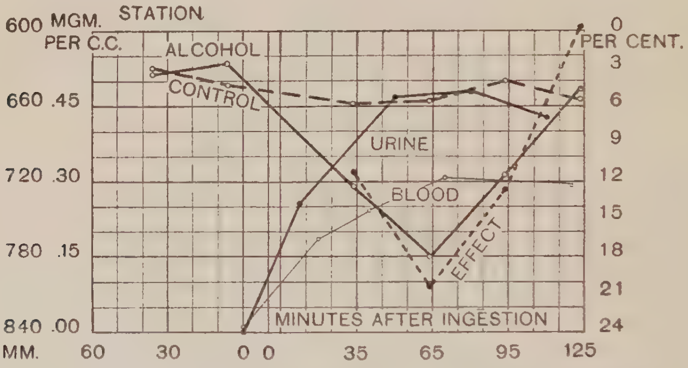

Fig. 46.—Average Effect of Very Dilute Alcohol on Static Equilibrium.

According to the averages for all the observations made following the alcohol, 5 subjects show a positive increase in sway, one man gives no change (due especially to the large minus value in the sixth period) and two subjects average better with the alcohol. The two last mentioned, *Jem* and *Sul*, demonstrated some increase in the swaying in the fourth period, but a smaller amount in the other three periods following the dose. This increase in swaying after the alcohol dose was very prominent in the case of *Faf*, the average effect being above 50 per cent. His records exert a large influence on the average for the group. As a means of comparison, the results for the other 7 men have been averaged by themselves and give the following values: +4.2, +11.8, +1.6, and −6.4, with a general average of +2.8 per cent. We may conclude that the usual effect of alcohol upon the static equilibrium measured in terms of the amount of swaying is more transitory than that with some of the other measurements.

Subjectively, the experience of vertigo following alcohol is much more prominent at those periods when the subject moves from one position to another, that is, from a sitting to a standing posture, or when turning quickly to walk in another direction.[a] In sitting or standing quietly, most subjects were not aware of increased unsteadiness. Some of them thought that they could stand even more quietly with the alcohol. This was particularly true of *Cef,* whose series of measurements unfortunately could not be completed. The alcohol did, to a certain extent, assist some subjects in making a good score in the standing test. *Jem* reported that following the alcohol he felt more care-free and less nervous about the tests. Such a relief from conscious inhibition would probably be somewhat of a help in the station test, especially as a comfortable physical attitude and contentment are most necessary for doing well.

AREA OF SWAY.

Graphic tracings were also taken in connection with the ataxiameter scores in the standing test. (See fig 11, p. 139.) As pointed out elsewhere,[b] the area which these graphic tracings cover represents a different phase of the performance from that shown in the ataxiameter reading. The subject who is being tested for his ability to stand motionless with eyes closed is trying to avoid swaying movements rather than to keep the writing-point at the vertex on a certain center. He has no accurate sense of such a center. He can not see it or feel it as in certain other steadiness tests. Consequently, it has seemed to us that the score for the amount of movement as registered by the movement adders is more logically the factor involved in the test as given rather than the extreme amplitude or range of movement. We have found, however, that usually the two phases of measurement give results which are in agreement, that is, when the total amount of movement has been large, the area of the tracing is also found to be large, but this is not always or necessarily true.

Each graphic tracing was measured by a glass plate ruled in square millimeters. The dimensions of the smallest rectangle that would contain the tracing when placed without regard to axis were multiplied by each other. The score in square millimeters is thus always larger than the actual area covered, as the tracings tend to be elliptical. When tracings have prominent irregularities, the rectangular area is much increased. The results of these measurements from the graphic records are given in table 63. Individuals appear to deviate from each other considerably more in the area of sway than they do in amount. The average area for the preliminary periods on the control days is 910 sq. mm. as compared with 961 sq. mm. for the preliminary periods on alcohol days. Following the control dose, there is an increase of about 50 sq. mm. in the third period and decreases of somewhat larger amount in the fourth and fifth periods, with a similar increase in the sixth period, so that the average for all periods is very nearly the same as the average for the preliminary periods, being a decrease of only 9 sq. mm. Following the alcohol, the changes are all increases and seemingly quite regular, being 218, 399, 459, and 163 sq. mm. for the four periods, with an average of 310 sq. mm. The alcohol effect in terms of per cent is large in comparison with most of the results which have been reviewed. These percentages for the four periods are, respectively, 18, 50, 57, and 12 per cent, with an average increase of 44 per cent in the area of sway following the alcohol. It was pointed out in the discussion of the amount of linear movement (see p. 240) that *Faf* increased the amount of his sway conspicuously after alcohol. As shown in the lower part of table 63, the changes in the area of sway with this subject are even more prominent, averaging 160 per cent. With all of the subjects, the alcohol effect in terms of per cent tends to be larger when computed from the graphic tracing, but the results are not so uniform as when figured from the linear score for swaying. If the period results for all of the 8 men are considered, there are only a few more plus signs than minus signs; hence the alcohol does not invariably increase unsteadiness in standing. In the averages for all periods following alcohol, 5 of the 8 men show increase of sway.

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[a] See Appendix, pp. 284, 285, and 290.

[b] Miles, Journ. Industrial Hygiene, 1922, **3**, p. 316.

TABLE 63.—*Steadiness of standing in terms of total area covered by the graphic record.*

Subject and type of experiment.	Area of sway tested at half-hour periods.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Control:	*sq. mm.*	*sq. mm.*	*sq. mm.*	*sq. mm.*	*sq. mm.*	*sq. mm.*	*sq. mm.*
Faf	1,114	1,752	1,646	2,044	855	1,169	1,429
Kom	830	1,003	942	599	976	821	835
Hic	904	839	895	910	1,084	1,843	1,183
Jem	602	513	522	513	491	512	510
Sul	662	1,005	820	680	636	685	705
Rir	1,841	1,103	1,730	840	1,299	1,373	1,311
Sut	359	693	572	613	730	523	610
Mow	723	608	585	538	609	772	626
Averages	**879**	**940**	**964**	**842**	**835**	**962**	**901**
Differences	(910)		+ 54	− 68	− 75	+ 52	− 9
Alcohol:							
Faf	1,233	1,375	2,601	4,300	4,163	2,890	3,489
Kom	944	1,143	1,338	1,407	1,404	601	1,188
Hic	987	1,052	1,259	1,015	1,287	1,419	1,245
Jem	589	489	360	665	607	531	541
Sul	1,153	1,125	1,048	751	774	769	836
Rir	1,146	1,589	1,353	1,293	1,782	1,731	1,540
Sut	509	531	862	511	646	462	620
Mow	718	780	612	940	700	586	710
Averages	**910**	**1,011**	**1,179**	**1,360**	**1,420**	**1,124**	**1,271**
Differences	(961)		+218	+399	+459	+163	+310
Effect of alcohol:							
Differences for group			+164	+467	+534	+111	+319
Per cent for group	(936)		+ 18	+ 50	+ 57	+ 12	+ 44
Per cent for individuals:							
Faf			+ 79	+174	+251	+135	+160
Kom			+ 27	+ 69	+ 31	− 35	+ 23
Hic			+ 23	− 5	+ 6	− 61	− 9
Jem			− 26	+ 31	+ 25	+ 7	+ 9
Sul			− 8	− 24	− 17	− 22	− 18
Rir			− 19	+ 39	+ 41	+ 33	+ 24
Sut			+ 57	− 18	− 15	− 11	+ 3
Mow			− 8	+ 45	+ 1	− 38	± 0
Average per cent			+ 16	+ 39	+ 40	+ 1	+ 24

SUMMARY OF RESULTS ON STATIC EQUILIBRIUM.

(1) Instability during walking and standing are common characteristic effects following the taking of alcohol. By a direct method of measuring static equilibrium or station, we have attempted to ascertain if 27.5 grams of ethyl alcohol, taken in a volume of 1,000 c. c., produce any marked increase in the swaying of the body when subjects with eyes closed attempt to stand motionless for 2 minutes.

(2) Following the taking of 1 liter of control solution at the same temperature as that of the alcohol solution, there was but little change in the ability to stand motionless, a slight increase of about 2 per cent in amount of sway being observed on the average for 8 subjects.

(3) After the alcohol dose, an increase in wavering as compared with the results after the control dose was found with all of the subjects at a time approximately 65 minutes following the ingestion (about 20 per cent). Most of the subjects also showed some increase in wavering earlier and later than this time.

(4) The alcohol effect appears more prominently on the area or gross amplitude of swaying than on the total linear amount of movement. Two hours following the alcohol, there was almost complete recovery from this instability.

(5) The subjects varied considerably in the intensity of alcohol effect demonstrated on this measurement.

FINGER MOVEMENTS.

By the method of performing the tapping test in this series of experiments, which is described on page 16, subjects usually execute from 50 to 85 oscillations in a period of 10 seconds. We have found that slight fatigue develops quite regularly within this period, the speed decreasing approximately 0.3 oscillation per 2 seconds.[a] It will be sufficient for our comparisons to consider the total number of oscillations performed in 10 seconds.

SPEED OF FINGER MOVEMENTS.

The data for the 8 subjects on the speed of finger movement are presented in table 64. The extreme range represented in the preliminary averages, for both control and alcohol days, is from 56.6 oscillations with *Jem* to 85.8 oscillations performed by *Hic.* The averages for the first preliminary periods on the control and alcohol days are practically identical (69.1 and 69.2 oscillations). The second preliminary period in both cases shows a decrease which appears slightly greater on the control day. The changes are clearly indicated in figure 47. In the period just following the alcohol and control doses, the averages are identical, 64.9 movements, and about 3 oscillations below their respective preliminaries. In periods 4 and 5 the rate after alcohol sinks still lower, being below the control in the corresponding periods by somewhat more than one oscillation in 68. The effect in percentage is therefore not large. For the periods in order after the dosage, there is a decrease in the number of finger movements executed of 0.9, 2.2, 1.8, and 0.7 per cent, with an average decrement of 1.4 per cent. The curve showing the effect of alcohol for this measurement (fig. 47), in comparison with the alcohol concentration in the urine and blood, gives the usual picture of the maximum effect occurring near the time of the maximum in the urine, and of a decrease in the effect especially prominent 2 hours after ingestion and before the alcohol concentration in the urine has greatly decreased.

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[a] Benedict, Miles, Roth, and Smith, Carnegie Inst. Wash. Pub. No. 280, 1919, p. 627; also Miles, Carnegie Inst. Wash. Pub. No. 266, 1918, p. 85.

Table 64.—*The speed of voluntary finger movements as influenced by 27.5 grams of alcohol taken in volume of 1,000 c. c.*

[Number of complete oscillations in 10 seconds.]

Subject and type of experiment.	Finger-movement speed at successive half-hour periods.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Control:							
Faf	63.8	59.9	58.8	60.7	60.7	58.6	59.7
Kom	77.9	77.8	75.1	73.7	75.1	78.4	75.6
Hic	83.8	79.7	76.1	76.5	71.3	73.0	74.2
Jem	60.6	56.6	54.9	55.5	57.0	57.8	56.3
Sul	62.0	60.2	58.3	60.6	62.4	63.4	61.2
Rir	62.4	60.7	60.1	61.7	59.3	59.5	60.2
Sut	64.5	62.2	61.8	59.3	60.5	60.6	60.5
Mow	77.4	76.1	73.8	73.5	74.0	73.5	73.7
Averages	**69.1**	**66.7**	**64.9**	**65.2**	**65.0**	**65.6**	**65.2**
Differences	(67.9)		**−3.0**	**−2.7**	**−2.9**	**−2.3**	**−2.7**
Alcohol:							
Faf	62.2	61.5	56.7	59.4	56.0	58.8	57.7
Kom	78.7	78.2	76.5	75.7	79.6	77.2	77.3
Hic	85.8	80.6	74.9	70.6	73.1	78.7	74.3
Jem	61.8	57.4	55.6	55.7	55.0	55.9	55.6
Sul	61.5	61.7	59.9	60.0	61.0	60.8	60.4
Rir	61.7	61.6	59.5	58.6	58.5	60.1	59.2
Sut	64.4	64.6	62.4	62.4	62.0	61.0	62.0
Mow	77.5	75.6	73.7	72.3	70.1	73.3	72.4
Averages	**69.2**	**67.7**	**64.9**	**64.3**	**64.4**	**65.7**	**64.8**
Differences	(68.5)		**−3.6**	**−4.2**	**−4.1**	**−2.8**	**−3.7**
Effect of alcohol:							
Differences for group	......	......	**−0.6**	**−1.5**	**−1.2**	**−0.5**	**−1.0**
Per cent for group	(68.2)		**−0.9**	**−2.2**	**−1.8**	**−0.7**	**−1.4**
Per cent for individuals:							
Faf	......	......	−3.4	−2.1	−7.6	+0.3	−3.2
Kom	......	......	+1.0	+1.8	+5.0	−2.3	+1.4
Hic	......	......	−3.2	−8.9	+0.5	+5.2	−1.6
Jem	......	......	−0.5	−1.4	−5.1	−4.9	−3.0
Sul	......	......	+1.8	−1.8	−3.1	−5.1	−2.1
Rir	......	......	−1.1	−5.2	−1.5	+0.8	−1.8
Sut	......	......	−0.8	+3.1	+0.6	−1.1	+0.5
Mow	......	......	+0.1	−1.3	−4.8	±0.0	−1.5
Average per cent	......	......	−0.8	−2.0	−2.0	−0.9	−1.4

The alcohol effect on the performance of finger movement shown in detail for individual subjects indicates that 6 of the 8 men execute a less number of finger movements after the alcohol, the average percentile decrease in efficiency for these men ranging from 1.5 to 3.2. The latter value is for *Faf,* who exhibited the very strong alcohol effect on station and the high alcohol concentration in the urine. In this case, the subjects who demonstrate an alcohol effect are closely grouped. The two, *Kom* and *Sut,* who gave a better performance after alcohol, are consistent in showing this at periods 5 and 4, respectively, but their average gain is small, 1.4 and 0.5 per cent, respectively. As a measure of motor coordination, the speed of finger movement therefore indicates a fairly consistent but small alcohol effect, which with the majority of our subjects is apparent, wholly aside from the consideration of preliminary level of performance.

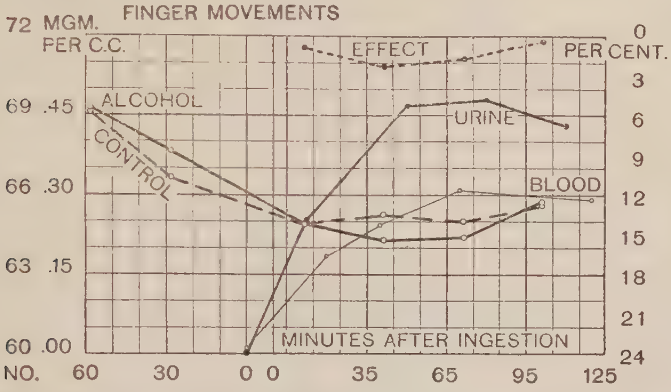

Fig. 47.—The Average Speed of Finger Movement for a Group of 8 Men After Ingestion of Very Dilute Alcohol.

Amplitude of Finger Movements.

With *Mow,* the practiced subject (see p. 143), there was a prominent alcohol effect upon the character of the finger movement, as well as on the speed. To ascertain if this is typical for our group of subjects, some measurements of the amplitude of the movements were made for the records represented in the data of table 64. At a specific location near the end of each record, the heights of 25 oscillations were measured in millimeters. There were thus 50 readings recorded, one-half representing movements of extension and the other half movements of flexion. The average of these has been taken as the average amplitude. The data arrived at in this way are presented in table 65. The amplitudes range from 16 to 45 mm. in the averages for the preliminary periods, with general averages of 29 and 27 mm. for the control and alcohol preliminary periods. Following the control dose, the amplitude decreases with all of the 8 subjects, the average decrease being 5 mm. The change following the taking of the alcohol solution was in the opposite direction. In terms of averages and of whole millimeters, we find that the finger movement is about 1 mm. larger after the alcohol as compared with the preliminary. When the control and alcohol results are compared, the effect of alcohol is seen to be an increase in the amplitude of the finger movement, amounting to 17.9, 14.3, 28.6, and 17.9 per cent for periods 3 to 6, and a total average increased amplitude of 19.7 per cent. The alcohol effect upon the different individuals as given in the lower part of the table shows comparatively few minus signs. All of the subjects, with the exception of *Mow*, have averages for the periods following the dose which are plus in direction and range from 7 to 48 per cent. Thus the results for average amplitude on *Mow* (see p. 149), the practiced subject, are not substantiated by those on the group and it is not possible to clear up this conflict at present. That the amplitude of the finger movement does not decrease after the alcohol as it does following the control solution is no doubt partly due to the fact, shown by our skin temperature results, that the hand is warmer after alcohol than after the control solution.

TABLE 65.—*The amplitude of the finger movements.*

Subject and type of experiment.	Finger-movement amplitude at half-hour periods.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Control:	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Faf	38	45	43	39	31	42	39
Kom	27	31	19	27	16	19	20
Hic	28	24	19	19	16	15	17
Jem	21	20	21	18	16	23	20
Sul	43	43	36	42	36	38	38
Rir	25	24	22	18	19	19	20
Sut	20	24	17	24	20	17	20
Mow	25	26	23	23	23	21	23
Averages	28	30	25	26	22	24	24
Differences	(29)		− 4	− 3	− 7	− 5	− 5
Alcohol:							
Faf	43	41	47	41	46	45	45
Kom	38	30	38	52	41	31	41
Hic	23	21	19	18	26	18	20
Jem	23	22	23	27	23	23	24
Sul	35	35	39	33	35	35	36
Rir	19	22	21	22	21	23	22
Sut	16	21	19	15	15	23	18
Mow	22	21	20	19	16	17	18
Averages	27	27	28	28	28	27	28
Differences	(27)		+ 1	+ 1	+ 1	± 0	+ 1
Effect of alcohol:							
Differences for group			+ 5	+ 4	+ 8	+ 5	+ 6
Per cent for group	(28)		+17.9	+14.3	+28.6	+17.9	+19.7
Per cent for individuals:							
Faf			+10	+ 5	+36	+ 7	+15
Kom			+44	+63	+63	+22	+48
Hic			+17	+13	+58	+29	+29
Jem			± 0	+32	+23	− 9	+12
Sul			+28	− 3	+18	+13	+14
Rir			+13	+35	+26	+35	+27
Sut			+24	−29	−10	+43	+ 7
Mow			+ 3	− 1	−11	+ 1	− 2
Average per cent			+17	+14	+25	+18	+19

VARIABILITY IN AMPLITUDE OF FINGER MOVEMENTS.

The amplitude of the finger movements, although no artificial stops were introduced, can not well exceed a certain limit, and with a large average amplitude it is only natural that the percentage variability should relatively decrease. The average coefficient of variability in the preliminary period is about 14.7 per cent. (See table 66.) Following the control dose, it changes to an average of 16.7 per cent and after alcohol to 17.2 per cent.

TABLE 66.—*Percentage variability in the amplitude of finger movements.*

Subject and type of experiment.	Variability in amplitude at half-hour periods.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Control:	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*
Faf	11.8	10.2	10.6	14.3	19.3	12.7	14.2
Kom	19.2	20.7	26.6	16.4	19.5	21.6	21.0
Hic	26.8	27.7	30.3	32.4	28.1	30.0	30.2
Jem	12.3	17.5	17.2	15.5	19.6	14.9	16.8
Sul	8.4	9.4	8.5	9.7	8.4	10.7	9.3
Rir	8.6	10.4	6.7	11.5	13.1	10.7	10.5
Sut	12.9	17.1	14.9	15.3	17.7	18.2	16.5
Mow	12.3	11.7	14.4	14.4	15.0	15.4	14.8
Averages	**14.0**	**15.6**	**16.2**	**16.2**	**17.6**	**16.8**	**16.7**
Differences	(14.8)		+ 1.4	+ 1.4	+ 2.8	+ 2.0	+ 1.9
Alcohol:							
Faf	10.7	9.0	11.7	12.3	12.1	10.1	11.6
Kom	14.7	17.6	17.1	14.6	19.1	12.8	15.9
Hic	26.6	26.5	32.7	28.0	21.5	33.5	28.9
Jem	17.4	11.3	21.8	26.7	20.9	15.7	21.3
Sul	8.6	8.7	6.6	8.9	8.6	10.1	8.6
Rir	10.8	11.5	9.6	11.5	11.9	13.5	11.6
Sut	17.2	19.4	21.1	17.0	16.6	13.4	17.0
Mow	10.8	11.7	14.2	20.0	32.1	22.7	22.3
Averages	**14.6**	**14.5**	**16.9**	**17.4**	**17.9**	**16.5**	**17.2**
Differences	(14.6)		+ 2.3	+ 2.8	+ 3.3	+ 1.9	+ 2.6
Effect of alcohol:							
Differences for group			+ 0.9	+ 1.4	+ 0.5	− 0.1	+ 0.7
Per cent for group	(14.7)		+ 6.1	+ 9.5	+ 3.4	− 0.7	+ 4.6
Per cent for individuals:							
Faf			+21.0	− 8.6	− 58.1	−14.3	−15.0
Kom			−31.5	+11.5	+ 18.8	−27.6	− 7.2
Hic			+11.5	−13.7	− 21.9	+15.6	− 2.1
Jem			+34.7	+79.6	+ 12.2	+ 8.8	+33.8
Sul			−19.3	− 6.8	+ 4.5	− 4.5	− 6.5
Rir			+11.5	−16.4	− 27.9	+10.6	− 5.6
Sut			+17.4	− 9.6	− 26.3	−48.5	−16.8
Mow			+ 4.3	+53.8	+152.2	+68.4	+69.7
Average per cent			+ 6.2	+11.2	+ 6.7	+ 1.1	+ 6.3

The average variability for the group of subjects is larger by 6.1, 9.5, and 3.4 per cent for periods 3, 4, and 5, and slightly smaller, −0.7 per cent, in period 6, with an average increase for all periods following the alcohol of 4.6 per cent. These group results are not strictly representative, however, as will be seen in the lower part of table 66, where the percentile effect is given for the individual subjects. It is true that in period 3, 6 of the 8 subjects gave substantial increases in the variability of amplitude. *Kom* and *Sul*, who do not show this increase, were the two individuals who demonstrate the largest amount of increase in amplitude in this same period. (See table 65.) In periods 4, 5, and 6, there are as many minus as plus signs, but the prominent effect of increased variability with *Jem* and *Mow* is sufficient to give the average a plus sign. *Mow* is the only subject who does not demonstrate in table 65 an increased amplitude of finger movement following the alcohol. Evidently, amplitude of finger movement and percentage variability of amplitude are more or less reciprocal expressions and both should be taken into account.

SUMMARY OF RESULTS IN FINGER-MOVEMENT TESTS ON EIGHT SUBJECTS.

Summarizing the results of the finger-movement tests, we may make the following conclusions:

(1) The ingestion of 1 liter of non-alcoholic fluid at 18° to 19° C. causes in itself a slowing in the rate of finger movement.

(2) The dilute alcoholic beverage (1,000 c. c. with 2.75 per cent alcohol) taken at the same temperature as the control solution causes a still more prominent slowing in the speed of finger movement amounting at maximum (40 to 70 minutes after ingestion) to a decreased efficiency of about 2 per cent, notwithstanding the fact that this dose of alcohol increases the skin temperature of the hands which can but facilitate speed in this test.

(3) The oscillation of a finger at maximum speed for a period of 10 seconds was the simplest psychomotor test used and required the least time for its execution. It offered an especially good opportunity for a spurt of effort for which, indeed, the instructions constantly called. Notwithstanding these conditions and the changes in skin temperature and pulse-rate, the dilute alcohol exercises a depressant influence on the speed of this motor function.

(4) Following the alcohol there was some increase in the amplitude of finger movement and no very definite change in the variability of the amplitude, whereas *Mow* (pp. 143 to 149) had shown decrease of amplitude and marked increase in variability. This is the only instance in which an effect found characteristic with *Mow* is not confirmed in direction when the same measure is used with the group of men.

EYE-HAND COORDINATION WITH PURSUIT PENDULUM.

A previous study with the pursuit pendulum indicated that in the first sets of trials there is rapid improvement from practice.[a] Subjects changed from an average of 15 c. c. per catch on the first trial set of 25 catches to 31 c. c. per catch on the tenth trial.[b] Up to the thirty-fifth trial, improvement was fairly regular, with a final record of approximately 38 c. c. per catch, or a total score for the 25 cups of 950 c. c. Judging from the preliminary averages (see table 67), a practice change was present in these alcohol experiments, also, which causes a difference in level for the preliminary performance on control days as compared with that on alcohol days. The average values for these cases are 883 c. c. and 904 c. c., respectively. The values for both of the preliminary periods on the alcohol days (see figure 48) are somewhat higher than the corresponding periods on the control days. The scores in both the control and alcohol tests are closely the same in the period following the ingestion (890 and 889 c. c.). During periods 4 and 5, the alcohol values are somewhat smaller than those on control days, not only by direct comparison, but also when the preliminary values are taken into consideration, this difference being equivalent to 30 or 40 c. c. For the group of 8 subjects, the scores for all periods following the taking of the alcohol show poorer motor coordination as indicated by less water caught from the pursuit pendulum. As shown in table 67 and figure 48, the percentage effects of alcohol in the four experimental

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[a] Miles, Psychol. Review, 1920, 27, p. 361.

[b] The possible catch was 50 c. c. For technique, see pp. 16 to 19.

TABLE 67.—*The effect of dilute alcohol on the efficiency of eye-hand coordination as tested by the pursuit pendulum.*

Subject and type of experiment.	Coordination tested at successive half-hour periods.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Control:	*c. c.*	*c. c.*	*c. c.*	*c. c.*	*c. c.*	*c. c.*	*c. c.*
Faf	851	890	826	870	921	899	879
Kom	842	852	835	858	899	917	877
Hic	896	964	902	914	972	984	943
Jem	886	876	940	952	942	951	946
Sul	767	778	831	830	832	826	830
Rir	1,021	1,049	1,053	1,010	1,042	1,054	1,040
Sut	842	839	887	880	880	883	883
Mow	861	907	848	921	872	831	868
Averages	**871**	**894**	**890**	**904**	**920**	**918**	**908**
Differences	(883)		**+ 7**	**+21**	**+37**	**+35**	**+25**
Alcohol:							
Faf	910	927	834	844	861	894	858
Kom	943	945	854	935	848	940	894
Hic	829	939	964	940	962	968	959
Jem	922	966	935	1,015	987	993	983
Sul	739	751	751	757	800	812	780
Rir	1,030	1,040	1,051	1,000	1,028	1,052	1,033
Sut	888	929	891	857	944	884	894
Mow	833	872	833	803	766	811	803
Averages	**887**	**921**	**889**	**894**	**899**	**919**	**900**
Differences	(904)		**−15**	**−10**	**− 5**	**+15**	**− 4**
Effect of alcohol:							
Differences for group	......	......	**−22**	**−31**	**−42**	**−20**	**−29**
Per cent for group	(894)		**− 2.5**	**− 3.5**	**− 4.7**	**− 2.2**	**− 3.2**
Per cent for individuals:							
Faf	......	......	− 4.5	− 8.3	−12.1	− 5.9	− 7.7
Kom	......	......	− 8.7	− 2.2	−16.5	− 8.3	− 8.9
Hic	......	......	+11.9	+ 7.9	+ 4.0	+ 3.3	+ 6.8
Jem	......	......	− 7.5	± 0.0	− 2.0	− 2.3	− 3.0
Sul	......	......	− 6.9	− 5.9	− 0.5	+ 1.8	− 2.9
Rir	......	......	− 0.2	− 1.0	− 1.4	− 0.2	− 0.7
Sut	......	......	− 7.3	−10.4	− 0.5	− 7.7	− 6.5
Mow	......	......	+ 1.8	−10.0	− 8.6	+ 1.3	− 3.9
Average per cent	......	......	**− 2.7**	**− 3.7**	**− 4.7**	**− 2.3**	**− 3.4**

periods for the group are −2.5, −3.5, −4.7, and −2.2 per cent, with an average of −3.2 per cent. At a point 90 minutes after ingestion (in period 5), the effect of the alcohol was apparently at its maximum. This is slightly later than the maximum concentration in the urine, but as the measurements are one-half hour apart, a closer correspondence in maxima can hardly be expected.

With the individual subjects in table 67, seven of the men after alcohol show decreased ability in this psychomotor test, the average decrease ranging from 0.7 to 8.9 per cent in the amount of liquid caught. Among these 7 individuals, one did not show a decrease in period 3, another showed no change in period 4, and two did slightly better in period 6, but in general the direction of change and the amount are very consistent. The largest effect was during periods 4 and 5, that is, 60 to 90 minutes after the alcohol had been taken. One subject, *Hic,* is a clear exception in the way the alcohol influenced the performance in the pursuit pendulum test. For the periods following the ingestion of alcohol, his averages are +11.9, +7.9, +4.0, and +3.3 per cent. This is a regular series of decreasing size, and all of fairly large magnitude. In the case of this man the results are considerably influenced by the fact that contrary to the general findings of the group, his performance in the preliminary periods on alcohol days averaged poorer (46 c. c.) than in the corresponding periods on the control days. It is noteworthy that with *Sut,* the subject used to the occasional taking of large quantities of alcohol, the effect of decreased efficiency was pronounced in this motor test. His results seem slightly inconsistent for period 5; the average effect is a decrease of 6.5 per cent, which is the third largest effect found with the men of the group. Of the 8 subjects, *Mow* had received more practice than any of the others. Furthermore, the cups used in his tests had a smaller opening (9.5 mm. instead of 19 mm.) for catching the water than those used by the other men. After the alcohol, *Mow's* performance was poorer in periods 4 and 5 by 10.0 and 8.6 per cent. In periods 3 and 6, he did slightly better, i. e., 1.8 and 1.3 per cent.

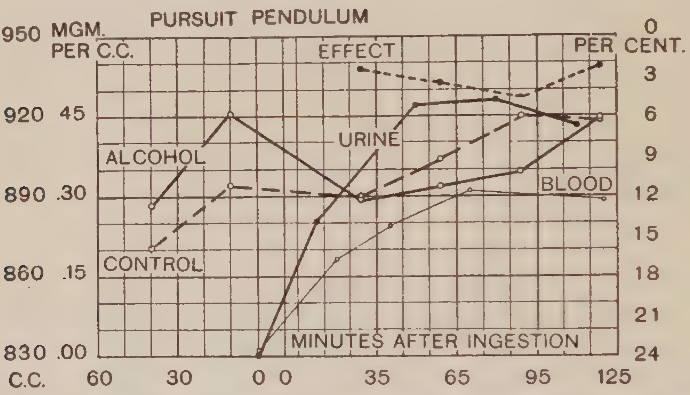

Fig. 48.—Average Results for 8 Men on Eye-hand Coordination in Tests with Pursuit Pendulum Following Ingestion of Very Dilute Alcohol.

The results of these tests with the pursuit pendulum are here summarized:

(1) In the case of this measurement the practice on the two preliminary days was not sufficient to obtain constancy and the subjects show preliminary levels that differ considerably for the control and alcohol base-lines.

(2) Of the 8 subjects employed, 7 demonstrate less accurate eye-hand coordination following the alcohol. The average decrease in efficiency for the whole group is 3.2 per cent.

(3) The alcohol effect is most prominent in periods 4 and 5. Here the coordination on an absolute basis is poorer than after the control dose and in relation to the preliminary performances amounts to a decrease in ability represented by 3.5 and 4.7 per cent.

(4) The decrease in accuracy of eye-hand coordination from period to period approximately corresponds with the changing alcohol concentration in the urine, but the maxima for the two curves do not exactly coincide.

Continuous Coordination with Pursuitmeter.

Notwithstanding careful instruction and preliminary practice days, for which the records were wholly discarded, the preliminary control and alcohol levels of performance in the test with the pursuitmeter do not agree so closely as could be desired. This can be seen from table 68 and in figure 49. Contrary to the scores obtained with the pursuit pendulum, the smaller values in this measurement represent the more efficient performance. Six of the men do better on the average for their preliminary periods on alcohol days than on control days. Some of these decreases are large, as, for instance, those for *Hic* and *Kom*, with whom they amount to about 200 points. *Rir* did slightly poorer in his preliminary for alcohol days and *Sut* did about 5 per cent poorer. His average preliminary on control days is 918, while the average for the preliminary periods on alcohol days is 970. Thus *Sut* is decidedly different from the other subjects in reference to his preliminary values, as the table (see lower part) shows him to be in reference to the effect of alcohol.

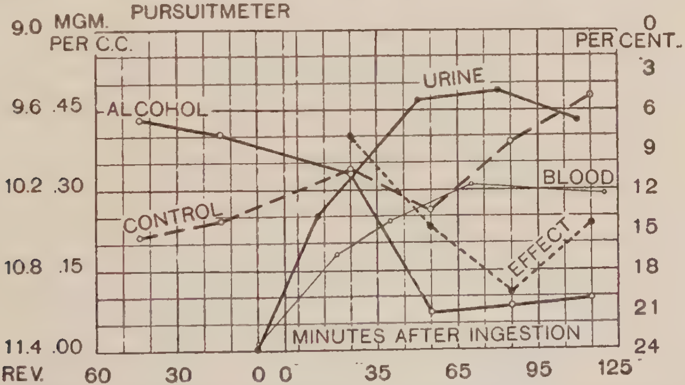

Fig. 49.—Continuous Eye-hand Coordination in Tests with Pursuitmeter Following Ingestion of Very Dilute Alcohol by a Group of 8 Men.

As may be seen in figure 49, the average results for the group of 8 men demonstrate a definite drop in the performance of this test following the ingestion of the alcohol. There is a wide divergence between the control and alcohol curves for periods 4, 5, and 6, which is prominent without consideration of preliminary values. If, however, we take these into account, it is seen that the alcohol performance for period 3 is less efficient than that following the control mixtures. Except for period 4, the averages on control days seem to improve gradually from beginning to end of the experimental session. The sharp decline in efficiency which occurred some 50 minutes after ingestion of the alcohol appears to be attributable to no other factor than to the alcohol. For the four periods succeeding the dose, the group results show percentage effects of 8.0, 14.9, 19.7, and 14.6 as indicated by the curve for alcohol effect on the chart. The average for all periods indicates decreased ability amounting to 14.3 per cent. As was found in the

TABLE 68.—*Effect of alcohol on adequacy of continuous reaction and coordination as tested by the pursuitmeter.*

Subject and type of experiment.	Pursuitmeter test at successive half-hour periods.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Control:							
Faf	1,286	1,269	1,161	1,128	1,034	1,202	1,131
Kom	1,154	1,059	1,059	1,003	978	895	984
Hic	1,399	1,495	1,329	1,372	1,373	1,287	1,340
Jem	1,093	1,124	1,104	1,173	1,090	1,037	1,101
Sul	1,498	1,466	1,413	1,546	1,426	1,267	1,413
Rir	776	720	739	747	698	665	712
Sut	912	924	928	996	956	925	951
Mow	321	297	298	328	323	320	317
Averages	**1,055**	**1,044**	**1,004**	**1,037**	**985**	**950**	**994**
Differences	(1050)		−46	− 13	− 65	−100	−56
Alcohol:							
Faf	1,177	1,227	1,113	1,622	1,829	1,277	1,460
Kom	953	923	878	963	923	951	929
Hic	1,147	1,211	1,240	1,284	1,300	1,300	1,281
Jem	1,061	1,007	1,031	1,143	1,087	1,093	1,089
Sul	1,412	1,411	1,701	1,588	1,584	1,604	1,619
Rir	752	758	807	927	812	698	811
Sut	949	991	963	983	943	903	948
Mow	293	305	338	386	385	352	365
Averages	**968**	**979**	**1,009**	**1,112**	**1,108**	**1,022**	**1,063**
Differences	(974)		+35	+138	+134	+ 48	+89
Effect of alcohol:							
Differences for group	......	......	+81	+151	+199	+148	+145
Per cent for group	(1012)		+ 8.0	+ 14.9	+ 19.7	+ 14.6	+ 14.3
Per cent for individuals:							
Faf	......	......	+ 2.3	+ 46.0	+ 70.2	+ 12.2	+ 32.7
Kom	......	......	− 1.2	+ 12.6	+ 11.1	+ 22.0	+ 11.1
Hic	......	......	+13.6	+ 13.7	+ 14.8	+ 21.4	+ 15.9
Jem	......	......	+ 0.2	+ 4.2	+ 6.7	+ 12.2	+ 5.8
Sul	......	......	+24.7	+ 7.7	+ 15.8	+ 28.1	+ 19.1
Rir	......	......	+ 8.1	+ 23.0	+ 14.2	+ 3.5	+ 12.2
Sut	......	......	− 1.8	− 6.9	− 6.9	− 7.8	− 5.9
Mow	......	......	+16.4	+ 22.4	+ 23.7	+ 13.8	+ 19.1
Average per cent	......	......	**+ 7.8**	**+ 15.3**	**+ 18.7**	**+ 13.2**	**+ 13.8**

tests with the pursuit pendulum, the strongest effect occurs in period 5. The pursuitmeter test immediately preceded that with the pursuit pendulum, so that these measurements have closely the same position in reference to the time of taking the alcohol.

Seven of the subjects demonstrate poorer coordination after alcohol, ranging from 5.8 to 32.7 per cent. The alcohol effect for six of these men was larger than 10 per cent for this measurement. The strongest effect was found in the case of *Faf*, an abstinent individual. One case, *Sut*, who apparently did better work in this test after the alcohol than before, was the individual who showed irregularity in his preliminary performance for the two groups of days. The routine in his case was the same as for the other subjects who quite regularly were able to do better in the test in the preliminary periods of the alcohol days. For some unknown reason, *Sut's* performance was contrary to this. Such a difference is sufficient to explain the change in sign and the average percentage improvement which he seems to demonstrate.

It is noteworthy that the alcohol effect should be approximately four times as great with the pursuitmeter as with the pursuit pendulum. The pursuitmeter test is not more difficult and probably for most subjects not so difficult as the active part of the pursuit-pendulum test, that is, during the 2 seconds when the subject is in pursuit of the pendulum he has to move more quickly and exert himself more than during moments when he is endeavoring to compensate the movements of the needle in the stimulus wattmeter. In the case of the pursuit pendulum, however, the test is discontinuous, as between each 2 seconds of effort at accurate coordination the subject has practically a rest period of 5 or more seconds when the cup is put down, another taken up, placed in position, and the subject makes ready to give the signal. When the pursuitmeter is operated, the whole test is continuous for 5 minutes. The subject is not so keenly aware of the presence of the experimenter and, as explained in the description of the technique of the apparatus, every moment counts in the integrated score.

The ability to rise momentarily above the depressing influence of alcohol or any other such factor that may be acting upon the organism is a well-known phenomenon. With conscientious subjects in the laboratory who are striving to do their best, autogenic reinforcement may play a prominent rôle, particularly in those tests which are of an intermittent character and require prompt, short responses. There is always the possibility that the laboratory environment may thus mask the effect which would commonly result from the same dosage if the men were outside the laboratory and working unobserved in their usual occupations. In developing the pursuitmeter, we hoped to provide a laboratory measurement which to some extent would correspond more nearly to skilled work outside the laboratory. These results on the effect of dilute alcohol upon the performance of the pursuitmeter test may be interpreted as indicating that this test is a sensitive measure for motor coordination, and not such a one as will permit a subject to adjust himself to its performance at a certain level, regardless of influences which are playing upon his central nervous system.

Briefly stated, the results found in this series of tests with the pursuitmeter are as follows:

(1) The pursuitmeter test requires considerable practice and subjects continue to show improvement for several days.

(2) Following the ingestion of 1 liter of control solution, there is but very slight change in the average score on the pursuitmeter, but following the ingestion of 1 liter of a beverage containing 2.75 per cent of alcohol there is a marked decrease in the ability of subjects to compensate the movements of the instrument.

(3) Seven out of eight subjects demonstrate definite decrease in their ability to perform the pursuitmeter test following dilute alcohol. The effect of the alcohol is most marked about 85 minutes after ingestion, when it amounts to approximately 19 per cent. The average effect shown for all observations after the ingestion of the alcohol (2 hours) amounts to a decrease in ability of about 14 per cent.

(4) The maximum concentration of alcohol in the urine appears to occur somewhat earlier than the maximum alcohol effect on this psychomotor ability.

Transliteration of Code Material.

The method of conducting the transliteration test has been fully explained on pages 26 to 28. The material and procedure were identical with all subjects.

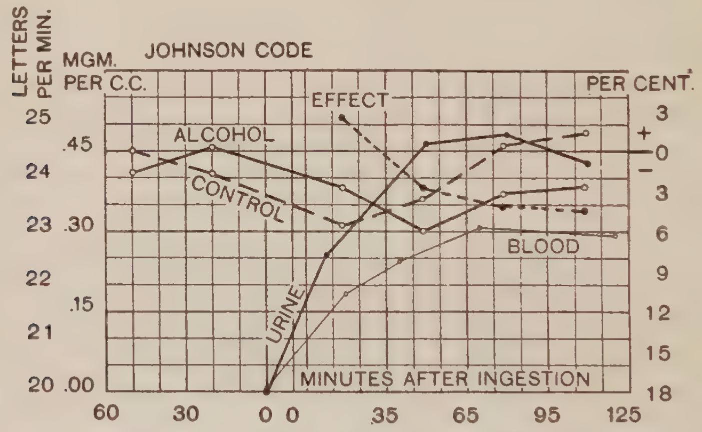

Fig. 50.—Average Results for a Group of 8 Men on the Effect of Alcohol Upon Performance of Substitution Code Test Following Ingestion of Very Dilute Alcohol.

In presenting the data in table 69 and the averages in figure 50, we record the number of letters correctly transliterated per minute. The average results for the preliminary period of control and alcohol days are practically identical, that for the control days being 24.3, and for the alcohol 24.4 letters per minute. The individual period averages for the various subjects give a range from 16.0 to 32.4. Errors were not very frequent, though some of the poorer scores were of course due to errors. The group averages following the control dose are 23.1, 23.6, 24.6, and 24.8 for periods 3 to 6. According to figure 50, after the ingestion of 27.5 grams of alcohol in a 1,000 c. c. solution, the efficiency in performing the substitution test is slightly better in period 3 than under control conditions, but in periods 4, 5, and 6 is poorer by an average of about 1 letter per minute. The effect of alcohol in terms of per cent as given in table 69 and in figure 50 is +2.5 for period 3 (an improved performance) and −2.9, −4.1, and −4.5 per cent for periods 4 to 6, inclusive. The maximum alcohol effect for the group therefore follows ingestion by some 80 minutes, and appears to come later than the maximum concentration in the urine.

TABLE 69.—*The influence of dilute alcohol on performance of the code test.*

[Number of letters correctly substituted per minute.]

Subject and type of experiment.	Efficiency in code test at successive half-hour periods.						Average after dose.
	Preliminary.		Following dose.				
	1	2	3	4	5	6	
Control:							
Faf	21.4	22.1	21.1	18.9	22.3	22.7	21.3
Kom	25.0	23.4	23.7	22.4	23.6	25.4	23.8
Hic	22.3	21.6	19.7	21.5	21.1	19.8	20.5
Jem	26.9	26.9	22.6	27.9	28.8	28.6	27.0
Sul	16.0	17.9	16.6	17.9	18.2	19.7	18.1
Rir	25.6	27.1	25.0	23.5	25.7	26.7	25.2
Sut	26.6	23.8	24.5	26.1	26.0	25.7	25.6
Mow	32.0	30.2	31.8	30.7	31.4	29.9	31.0
Averages	**24.5**	**24.1**	**23.1**	**23.6**	**24.6**	**24.8**	**24.0**
Differences	(24.3)		**− 1.2**	**− 0.7**	**+ 0.3**	**+ 0.5**	**− 0.3**
Alcohol:							
Faf	21.9	23.6	22.8	25.0	23.6	22.9	23.6
Kom	23.7	21.8	21.6	22.3	22.0	23.5	22.4
Hic	22.5	22.2	18.8	18.9	19.4	20.2	19.3
Jem	25.6	27.2	25.2	25.8	28.2	24.2	25.9
Sul	18.0	19.2	19.5	15.0	15.9	17.1	16.9
Rir	25.9	26.7	26.4	25.5	25.4	26.1	25.9
Sut	24.4	23.6	25.7	23.0	26.4	24.9	25.0
Mow	30.7	32.4	30.0	28.4	29.0	31.3	29.7
Averages	**24.1**	**24.6**	**23.8**	**23.0**	**23.7**	**23.8**	**23.6**
Differences	(24.4)		**− 0.6**	**− 1.4**	**− 0.7**	**− 0.6**	**− 0.8**
Effect of alcohol:							
Differences for group	......	......	**+ 0.6**	**− 0.7**	**− 1.0**	**− 1.1**	**− 0.6**
Per cent for group	(24.4)		**+ 2.5**	**− 2.9**	**− 4.1**	**− 4.5**	**− 2.3**
Per cent for individuals:							
Faf	......	......	+ 3.1	+22.9	+ 1.3	− 3.6	+ 5.9
Kom	......	......	− 3.0	+ 5.5	− 0.9	− 2.1	− 0.1
Hic	......	......	− 5.9	−13.5	− 9.5	± 0.0	− 7.2
Jem	......	......	+11.6	− 6.0	− 0.4	−14.6	− 2.4
Sul	......	......	+ 7.3	−25.3	−21.9	−23.6	−15.9
Rir	......	......	+ 5.7	+ 8.0	− 0.8	− 1.9	+ 2.8
Sut	......	......	+ 9.8	− 7.7	+ 6.5	+ 1.6	+ 2.6
Mow	......	......	− 7.3	− 8.9	− 9.2	+ 2.9	− 5.6
Average per cent	......	......	**+ 2.7**	**− 3.1**	**− 4.4**	**− 5.2**	**− 2.5**

Bearing in mind that in table 69 a plus sign denotes improvement and a minus sign loss of ability in this test, we observe that the 8 individuals demonstrate in their period results 12 plus signs and 19 minus signs, while there is one 0. The tendency is minus, especially in periods 5 and 6, and minus values are in the majority in period 4, but plus signs predominate in period 3. Five of the 8 subjects indicate, on the average, poorer ability in the substitution after the alcohol, but one of these subjects, *Kom*, indicates an extremely slight minus average, although in three of the periods following alcohol the direction was minus. This alcohol effect is strikingly evident with *Sul*, who demonstrates fairly consistent results in periods 4, 5, and 6, with an average decrease in ability for the observations following alcohol of −15.9 per cent. *Faf*, who in some of the other measurements has had a strong alcohol effect of a depressant nature, in this case, especially in period 4, in which his percentage effect is the largest plus value in the table (22.9 per cent) has a total average result of +5.9 per cent. *Rir* gives somewhat larger plus values in periods 3 and 4 than his minus values in periods 5 and 6; consequently his average is +2.8 per cent. *Sut*, the occasional extreme drinker, has an average effect of +2.6 per cent. It is noteworthy that in period 4, following the alcohol, his decrease in ability was marked, amounting to −7.7 per cent.

Summarizing the results, we may say that:

(1) The code or substitution test involves both accuracy and speed and of our various measurements is the nearest approach to mental work. Some 20 variations of this test, which appear to be of equal difficulty, have been worked out by Drs. Johnson and Paschal, and these were used in our study of the influence of dilute alcohol.

(2) The performance of the code test is not poorer immediately after the alcohol, but from 1 to 2 hours after the ingestion appears to be poorer by approximately 5 per cent.

(3) Of the 8 men used in the experiment, 6 give indication of decreased ability in the test, especially during the second hour after the alcohol ingestion.

(4) There is no evidence of recovery in the latter part of the experimental session, as has been found in several other measurements, and the maximum alcohol effect appears somewhat later than the maximal concentration in the urine.

SUMMARY FOR INFLUENCE OF DILUTE ALCOHOL ON GROUP OF YOUNG MEN.

The curves illustrating the average effect of alcohol found with the men studied have been assembled in a chart (fig. 51) that they may be conveniently compared. These curves have been presented individually on separate charts in discussing the results for different measurements in the preceding pages, and the combination chart is arranged essentially in the same form. The scale on the left is in milligrams per cubic centimeter and applies to the concentration of alcohol in the urine and in the blood. The curve for alcohol in urine is the average which we have commonly used. (See table 56, p. 218.) The blood curve represents the results of observations when both blood and urine samples were taken for comparison. (See table 54.) The time on the abscissa begins with the complete ingestion of the alcohol. The interval (*D*) between the two zeros of the abscissa represents the 10 minutes for drinking the dose. Following this was an interval of 5 minutes (*R*) during which the subject sat quietly in a steamer chair;

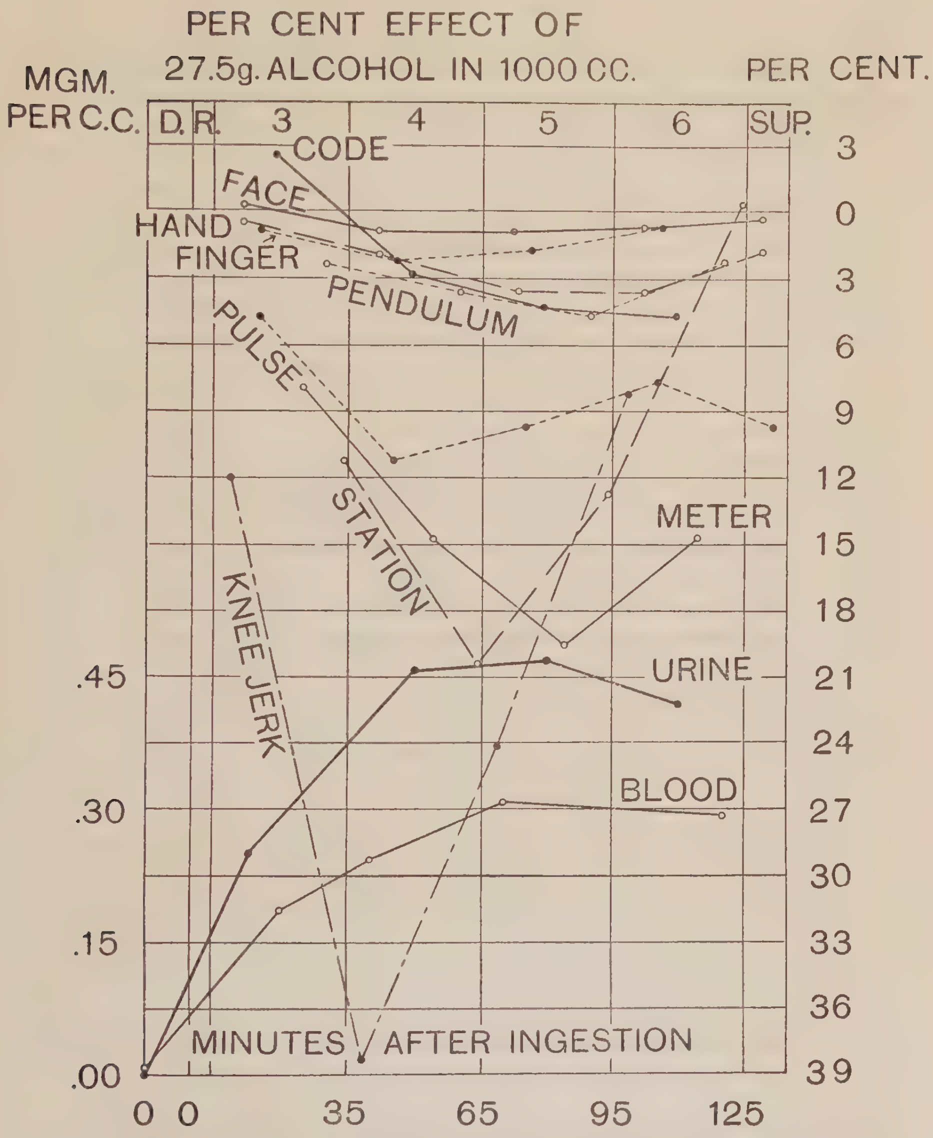

Fig. 51.—Curves Showing Average Effect of Dilute Alcohol (27.5 Grams in 1,000 c. c. Solution) upon 9 Neuro-muscular Processes.

The results, which are derived from as many control experiments as there were alcohol experiments, embody the findings for 8 different men. The scale under "Mgm. per c. c." applies to the two curves for alcohol concentration in urine and blood which are designated "Urine" and "Blood." The 10-minute interval when the liter of 2.75 per cent alcohol diluted with grape juice and water was ingested is designated as "*D.*" Following the dose was a rest period, *R,* of 5 minutes. The four 30-minute periods of measurement after the completed ingestion are indicated by 3, 4, 5, and 6. These presuppose two 30-minute periods before ingestion to serve as daily normals. Following period 6 there were supplementary (*Sup.*) observations on pulse-rate and skin temperature. The per cent scale at the right applies to all the curves except "Urine" and "Blood."

beyond this are the four 30-minute periods (3 to 6, inclusive) which provided for a like number of repetitions of the series of measurements.

The plotted points represent the actual time positions following complete ingestion at which the various measurements were made, except with the urine curve on which the points are placed midway of the collection periods. The neuro-muscular tests were taken in the following order: knee-jerk; skin temperature (face and hands); pulse-rate; finger movement; code test; pursuitmeter; pursuit pendulum; and station.

All of the 9 curves representing the influence of alcohol are in terms of per cent. The scale at the right side of the figure is to be applied to these curves. Minus and plus signs can not appropriately be attached to this scale, since the signs do not invariably have similar meaning in terms of alcohol effect. A downward direction of a curve or plotted position below the 0 in the per cent scale (see upper right corner of the chart) indicates an alcohol effect which is in the direction of a decrease in physiological or psychological efficiency.

The significance of the direction of the alcohol effects on speed of finger movement, code test, pursuitmeter, pursuit pendulum, and station measurements is easily understood. If the performance in these tests after alcohol is inferior to that following the non-alcoholic dose, the condition may reasonably be thought of as decreased efficiency or as a depressant action of alcohol. Actually we find that following dilute alcohol the rate of finger oscillation is slower, the number of code letters transliterated per minute is reduced, the deflections of the pursuitmeter needle are less adequately compensated, the amount of liquid caught from the swinging pendulum is smaller, and the subjects are less steady when trying to stand motionless. All of these tests concern voluntary functions and, to a great extent, are within the control of the subject, who has received careful and repeated instructions in what he is to strive for when performing them. The laboratory conditions have set a certain kind of efficiency as a goal. On the other hand, patellar reflex, pulse-rate, and skin temperature were measurements in which the subject was to refrain from striving for any particular result. He was to be completely passive.

The patellar-reflex amplitude was considerably smaller after alcohol, and no argument appears necessary to justify our calling this a depressant effect; to write "decreased efficiency" is hardly apt. The radial pulse-rate was definitely more rapid after alcohol and the skin temperature was higher. These two results are concordant, and when it is recalled that, so far as possible, similar physiological demands are made on the organism after the ingestion of both alcohol and control beverages, the functional level resultant from alcohol appears to represent poorer physiological efficiency. Dodge and Benedict[a] have reviewed the grounds for assuming that a faster pulse-rate from the ingestion of alcohol is due to a depressant effect on the vagus center. It may reasonably be assumed that the increased skin temperature is due to a decreased tone in the capillaries, with resulting dilation of these vessels.[b] Hence these effects on the circulatory functions, while they have popularly been considered evidences of alcohol stimulation, are in reality probably produced by the depressant action of this agent. On this basis the results for the different measurements discussed in this chapter are not in conflict, but agree in showing measurable depression.

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, p. 233, et seq.

[b] Krogh, The anatomy and physiology of capillaries, New Haven, 1922, p. 123 et seq. This may perhaps partly account for the decreased psycho-galvanic reflex found after alcohol by Whately Smith (The measurement of emotion, London, 1922. Chap. VI, pp. 124, et seq., "Experiments on the effects of alcohol").

The alcohol seems to influence particularly the knee-jerk, station, pursuitmeter coordination, and pulse-rate. The station and pursuitmeter curves, which occupy an intermediate level between those for the pulse-rate and the knee-jerk, both make relatively small demands upon the subject, but the demand is a continuous one. Any relaxation of effort and attention is reflected in the scores which result. In both cases the scores are cumulative in nature, so that all is combined in one total to represent the adequacy of the performance. Both these tests are believed to have many counterparts in the daily activities of industrial operations. They are sensitive measures of the influence of superimposed factors, but experience has shown, as is true of motor tests in general, that care must be exercised in providing a suitable period of initial practice before experimentation.

There are five measurements in which the maximum effect was less than 5 per cent. These, closely grouped at the top of the figure, are skin temperatures, finger movement, pursuit pendulum, and code test. The skin temperature is a very stable physiological factor relative to the physical scale on which it is measured. The actual percentage change is not so significant as the direction and the magnitude of change in terms of degrees. Three plotted points in the chart appear above the zero per cent line. These are code, period 3; face temperature, period 3; and station, period 6; otherwise the average effects are all in the same direction, so that no one of the eight measurements used with the group of men consistently shows an alcohol effect out of accord with the general picture of all the measures.

A progressive increase in the intensity of alcohol effect in period 4 as compared with period 3 is demonstrated in every instance by the nine curves in the chart. Excepting with the curve for code, there is always a less effect in period 6 than is found in period 5. Therefore the alcohol effect from a single dose of the size used has a characteristic temporal course of increase and decrease within 2 hours. The maximum effect was obtained 35 to 95 minutes following the ingestion of the dose. This, as seen in the chart, covered the period of the maximum concentration of alcohol in the urine and in the blood. No matter where the points on the urine curve are plotted, it is evident that the effect of the alcohol is strongest just prior to or coincident with this maximal concentration. Essentially the same relationship was found in some earlier experiments on *Mow*.

The presentation of the data discussed in this chapter may be concluded by the following general statements:

(1) When ethyl alcohol (27.5 grams diluted in 1,000 c. c.) is taken in a single portion and without food, the alcohol concentration in venous blood and urine rises rapidly. While both reach their maximal concentration at about the same time, that for the urine is usually 40 to 50 per cent higher than that for the blood. The maximal concentration occurs 60 to 90 minutes after complete ingestion and in the urine reaches approximately 45 mg. per 100 c. c. The rise in the concentration curve is much more rapid than the fall.

(2) The curve for the alcohol concentration in the urine is indicative of the absorption and utilization processes and as such is a physiological datum which may be compared with the temporal intensity of alcohol effect on neuro-muscular processes.

(3) The taking of 1 liter of non-alcoholic liquid at 18° to 19° C., and within 10 minutes, of itself exercises an appreciable influence on some measured processes: (*a*) the pulse-rate is slowed about 5 beats per minute; (*b*) the skin temperature is definitely lowered; (*c*) the patellar-reflex amplitude is heightened; and (*d*) the speed of voluntary finger oscillation is reduced. Other processes were less markedly influenced and this effect from what seems to be an internal cooling of the body is, in general, only temporary.

(4) The ingestion of 1 liter of a solution containing 2.75 per cent of alcohol by weight taken at 18° to 19° C., in contrast to the non-alcoholic or control dose, produced effects as follows: (*a*) the pulse-rate for 7 men increased 4.4 to 17.8 per cent, or an average of 8.8 per cent for 2 hours; (*b*) skin temperature increased to a maximum of 0.3° C. for face and 1.2° C. for hands; (*c*) patellar-reflex amplitude decreased at maximum 38 per cent; (*d*) ability to stand motionless with eyes closed was reduced by about 20 per cent, 65 minutes after ingestion; (*e*) speed of voluntary finger movements was reduced about 2 per cent; (*f*) accuracy of eye-hand coordination in pursuit movements was reduced about 4 per cent in spite of spurts of effort; (*g*) compensation of the pursuitmeter was poorer by 14 per cent for the average of all periods; and (*h*) ability to transliterate code material was 4 or 5 per cent less. All of these results appear to be concordant and are interpreted as evidence of decreased efficiency, physiological and psychological.

(5) The maximal alcohol effect found in the various processes usually measured occurs just prior to or coincident with the maximal alcohol concentration found in the series of urine samples.

(6) The results for the influence of very dilute alcohol on the group of men studied in this chapter thoroughly substantiate the direction and approximate intensity of the more extended results reported on one trained subject. (See pp. 125 to 202.)[a] These group results are furthermore in essential agreement with those obtained in the series of typewriting experiments in which the alcohol dosage was much more concentrated. (See pp. 29 to 91.)

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[a] See, also, Hollingworth, Therapeutic Gazette, February 15, 1921, and page 203 (footnote *b*) of this monograph, for brief statement of his results.

CHAPTER VII.

RELATIONSHIP OF ALCOHOL EFFECT TO ALCOHOL IN URINE.

The diffusibility of ethyl alcohol is a well-known characteristic of this substance. When placed in the stomach it very soon appears unchanged in the blood and is also recoverable from other body fluids and tissues.[a] Alcohol absorption and elimination or utilization has been studied repeatedly, most of the work having been done with animals. Those who have interested themselves in the psychological or physiological effects have usually given little or no attention to the simultaneous study of the absorption phase of the problem. It is only through observations of this latter type that the real intensity of alcohol dosage from a particular beverage and set of experimental conditions may be known. The problem of relating the direction and intensity of physiological or psychological effects to the incidence and changing concentration of a substance like ethyl alcohol in the organism is relatively new. Such a comparison is peculiarly possible in studies on the influence of alcohol, especially if the alcohol concentration in urine collected at frequent intervals gives, as suggested by Widmark, a correct picture of the changing course of absorption and utilization. From experimental evidence presented in Chapter VI,[b] we have found that the curve for alcohol concentration in the urine agrees very well with that for venous blood in respect to the rate and period of rising concentration, time of maximum, and beginning of fall. The urine curve is regularly at a higher level than that for venous blood. This difference, since the curves are very much alike in other respects, is not apparently a disadvantage.

Comparison of measured quantitative effects with the height of alcohol concentration in the urine samples may be made between different sets of experiments or, more minutely, between different time periods within one set. Observations of the latter type occur in the discussions of data given in Chapters V and VI, and such relationships will be further considered after the more general comparison is made.

Does the average level of the alcohol-urine curve correlate with the intensity of the alcohol effect? The original data at hand for answering this question are of two classes:

1. Those obtained with varying conditions and volumes. An experimental beverage containing 2.75 per cent alcohol by weight was taken under different conditions and in various amounts, several series of experiments being made with one subject.

2. Those obtained with different men. Doses of the same dilution and the same volume were given to men who differed in body-weight, and also in alcohol experience.

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[a] New data on the diffusion of ethyl alcohol from the mother into the foetus, and the presence of alcohol in the milk of nursing mothers has been published recently. See Olow, Biochem. Zeitschr., 1922, **134**, p. 407, and same journal, p. 553. The original and well-known work of Nicloux on these subjects was published in 1900.

[b] See also Miles, Journ. Pharmacol. and Exp. Therapeutics, 1922, **20**, pp. 265–319.

COMPARISON OF AVERAGE RESULTS FOR DIFFERENT CONDITIONS.

The 11 series of alcohol experiments on *Mow,* with 15-minute periods, were made under such a variety of conditions that the levels of the alcohol-urine curves vary appreciably. The different series may be easily ranked with respect to the height of the curves for alcohol concentration and also for the combined intensity of alcohol effect. Such ranking may be based solely upon the maximal values or upon the entire series of results. In this comparison, the latter more inclusive basis has been used. In all the experiments in these 11 series there were 14 periods of measurement after the ingestion of alcohol, each 15 minutes in length, so that the courses of the alcohol-urine curve and of the alcohol effect were followed for 3½ hours. The first step in ranking the results was to group these short periods into larger time units. Periods 3, 4, 5, and 6 have been grouped as the first hour, 7, 8, 9, and 10 as the second hour, 11, 12, 13, and 14 as the third hour, and finally periods 15 and 16 as the fourth hour after alcohol ingestion. For each experimental series and for each measurement the percentage effects found in the first, second, third, and fourth hours have been averaged separately. For example, the station tests in series A (see p. 183) show an increase in swaying in periods 3, 4, 5, and 6, of 11.1, 29.3, 24.6, and 39.5 per cent; the average for the first hour is therefore 26.1 per cent. Series B for the same test and hour gives an average of 21.5 per cent. Of the 11 series the smallest average alcohol effect indicated for station in the first hour was ranked 1; the other percentage averages were ranked in sequence, the largest effect being considered as 11. The 11 averages for the second, third, and fourth hours after alcohol were ranked in the same way. Then the ranks for the 4 hours were totaled for each series. By means of these totals, the 11 series were then ranked for the station measurement. When each of the 11 series had thus been ranked on the six measurements, a final ranking was made by totaling. Thus, series F, in which was given a double dose (2,000 c. c. containing 2.75 per cent of alcohol), had the following ranks for the various measurements: station, 11; finger movement, 10; pursuitmeter, 11; eye movement (left), 11; eye movement (right), 11; code test, 11; with a grand total of 65 points. Series J, in which a half-liter of milk was taken 1 hour after the alcohol, had the following ranks: station, 4; finger movement, 2; pursuitmeter, 5; eye movement (left), 2; eye movement (right), 1; code test, 1; with a grand total of 15. As 15 was the smallest total, series J received a final rank of 1 as exhibiting in general the least alcohol effect of the 11 series. Similarly, 65 being the largest series total, series F received the final rank of 11. The values for the alcohol concentration in the urine for the 11 series were also grouped, averaged, and ranked in exactly the same way that station or any other measurement was treated, the lowest score for alcohol concentration being ranked as 1 and the highest score as 11.

The final results from this ranking, which is the most direct method of obtaining a comparative statement for the relation of alcohol effect and alcohol concentration in the urine, may thus be represented as follows:

Series of alcohol experiments:[a]	A	B	C	D	E	F	G	H	I	J	K
Rank for alcohol concentration in urine samples.	6	7	5	9	10	11	4	1	3	2	8
Rank for intensity of alcohol effect.	6	7	5	10	9	11	3	2	8	1	4

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[a] For description of the distinguishing features of these various series, see p. 181.

The correspondence between these pairs of ranks is too nearly identical to be a matter of accident. A high degree of positive correlation is indicated. Four of the experimental series (A, B, C, and F) have identical ranks in both factors; five more series (D, E, G, H, and J) each have ranks that are within 1 point of each other. In the remaining two series the ranks differ considerably. These are series K, in which there were periods of physical work, and series I, in which 0.5 liter of water was given 1 hour after the dose. The ranks for the alcohol effect in series I are with the various measurements as follows: station, 4; finger movements, 8; pursuitmeter, 8; eye movements (left), 6; eye movements (right), 8; code test, 9. The alcohol concentration in the urine for this series ranked for the 4 hours are 2, 3, 3, and 4. There is therefore a definite difference in this series, which we can not explain. Neither can we satisfactorily explain the effect of physical work in reducing the measured influence of alcohol, while the alcohol-urine curve still remains at a fairly high level. In these rather complicated alcohol experiments a wide range of conditions was covered, and naturally the data for any one set of conditions are quite limited. Nevertheless the comparison for these many experiments on *Mow* clearly indicates a direct relationship between intensity of effect on the nervous system and content of alcohol in urine.[a]

COMPARISON OF RESULTS WITH DIFFERENT MEN TO DETERMINE INDIVIDUAL DIFFERENCES.

When several men are given identical doses of alcohol and follow the same experimental routine, will each maintain the same rank in alcohol effect that he shows for alcohol concentration in the urine? To answer this question, we have examined the data obtained in the 9 measurements used as indicators of the alcohol effect[b] in the study of the group of subjects described in Chapter VI. Rank 1 was assigned to that subject who, on the average, gave the least alcohol effect, judging the typical influence on each measured process to be that demonstrated by the average for the group. Rank 7 or 8, according to the number of subjects on whom data were collected in the particular measurement, was assigned to that individual who demonstrated the largest average effect of alcohol upon the factor measured. In ranking these individuals, a preliminary table was made up for the 8 subjects and their ranks with the various measures tabulated in series. These ranks were then summed up to secure the final or general rank for each man. Two of the men did not have a complete series of tests, for it will be recalled that the knee-jerk could not be taken with *Hic* and that the observations on *Mow* did not include pulse-rate, skin temperature, and knee-jerk. The subjects were also compared and ranked on the basis of the height of alcohol concentration in the urine. (See table 56, p. 218.) For this comparison, the four average values, i. e., those taken at 35, 65, 95, and 125 minutes following the ingestion, were totaled for each subject and the totals were then compared. Two subjects, *Hic* and *Sul*, happen to have the same total for the four values, but *Hic* has arbitrarily been assigned a position above *Sul,* inasmuch as the concentration in his first two alcohol periods was higher, indicating more rapid absorption in the early part of the experiment.

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[a] In two other series of experiments on *Mow*, grape-juice-alcohol of 1920 and cider-alcohol of 1920, trustworthy urine results were obtained. The cider set gave the higher concentrations and also the stronger effects as may be seen in Chapter V, p. 174.

[b] Skin temperature is included twice in this numbering, as the temperatures of the face and of the hands are considered separately.

There were 6 of the 8 men whose previous experience with alcohol and practice in the various tests were apparently nearest in conformity, so that their results could rightfully be compared. This grouping would exclude *Sut,* as his experience with alcohol was widely different from that of the other men, and the data obtained with him were very irregular, especially as to the concentration of alcohol in urine and also in the blood. This irregularity is readily seen by contrasting the results of his two alcohol days, October 14 and 20, when the difference was much greater than that found between the two similar days of any other subject. *Mow* is likewise excluded from this general comparison on account of his very extensive practice with the tests; furthermore, as stated, his series did not include observations of the pulse-rate, skin temperature, and knee-jerk.[a]

The six men who may be logically compared with one another rank as follows in regard to the average alcohol concentration in urine and effect of alcohol on measured efficiency, proceeding from the greatest to the least in each case:

Rank	6	5	4	3	2	1
Alcohol concentration	Faf	Jem	Hic	Sul	Kom	Rir
Alcohol effect	Faf	Jem	Hic	Kom	Sul	Rir
Body-weight from lightest to heaviest	Jem	Sul	Hic	Faf	Kom	Rir

These ranks are parallel, except that the positions of *Sul* and *Kom* are reversed in the two comparisons. The subject (*Faf*) who shows individually the most marked average effect of alcohol, taking the results of all the measurements into consideration, is the one who also shows the highest concentration of alcohol in the urine (and quite probably in the blood). Likewise the individual who demonstrates the least alcohol effect among the men of this group also ranks lowest in the concentration of alcohol in the urine. Similar identities of rank are found in the intermediate positions, so that these data as a whole indicate a high order of positive correlation for ordinary subjects and dilute alcohol solutions between the intensity of the toxic effect and the height of the alcohol concentration occurring in the urine samples.

As the alcohol doses were identical for all of the men, the comparative body-weights of the different subjects must be taken into consideration. The six men rank in body-weight from the least to the greatest as follows: *Jem,* 63.1; *Sul,* 66.8; *Hic,* 67.6; *Faf,* 70.2; *Kom,* 73.4; and *Rir,* 75.0 kg. From this it will be seen that there is some relationship between body-weight and alcohol concentration in the urine. It might be expected that the largest man would show per cubic centimeter of body fluid the lowest alcohol concentration, and vice versa for the smallest man. In this comparison, three subjects, *Rir, Kom,* and *Hic*, maintain the same rank in order of decreasing weight in both series, i. e., 1, 2, and 4. *Jem,* who is the lightest man, shows next to the highest alcohol concentration. *Sul* is fifth in point of body-weight, but third in point of alcohol concentration in the urine, that is, he has a considerably lower concentration than might be expected in comparison to his body-weight. He was the one subject who served in the morning and in the post-absorptive condition. There is therefore the undemonstrated possibility that under fasting conditions the alcohol may have been more rapidly used by the organism than in the case of the other subjects with whom it was separated from the previous food by approximately 5 hours. At least the facts are that *Sul*, although of light body-weight, shows a relatively slighter alcohol concentration and a still less pronounced alcohol effect than most of the others, since in smallness of effect he stood second.[a] The most striking deviation is in the case of *Faf*, who was third in weight but sixth in concentration and in the intensity of alcohol effect. *Faf* was the only man who had been completely abstinent, since he does not remember having taken alcoholic beverages at any time prior to these experiments.[b]

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[a] In place of these measures, eye movements, eye reactions, and sensory-threshold determinations were made.

Probably the individual differences in the effect which alcohol is frequently said to exert on the central nervous system of different men therefore rests to a considerable extent on differences in the absorption of alcohol. Body-weight and tolerance or habituation are undoubtedly factors of importance. We must continually recognize the possibility of subjects like *Sut*, who, if included in this comparison, would have ranked fourth in alcohol effect, the sum total of his ranks being nearly the same as that of *Kom*. As seen in table 56 and figure 41 (pp. 218 and 219), *Sut* had the highest average concentration of alcohol in the urine.[c] He is therefore an exception, so far as our data indicate the direct correlation between concentration and effect. It seems that the solution of his case is bound up with the problem of tolerance, both physiologically and psychologically developed.[A]

NOTE A.—*Sut* is described on page 208 as an occasional extreme drinker, and credited with being able to consume very large amounts of alcoholic liquors without apparent intoxication. Contrary to the results for all the other subjects included in tables 54 and 55 (pp. 212 and 213), he does not show a higher alcohol concentration in the blood or in the urine with the more concentrated dose. He is also the one exception in table 56 (p. 218) in reference to the total volume of urine following the taking of alcohol as compared with the control dose, showing somewhat less excretion with the alcohol. On October 14, the alcohol concentration in the four urine samples was found to be 0.28, 0.69, 0.69, and 0.64 mg. per cubic centimeter, which are remarkably high values for these conditions. He received the same amount of alcohol (27.5 grams in 1,000 c. c.) as on September 27 (see tables 54 and 55) and on October 20 (see table 56). In the October 14 experiment, the dose was taken nearly 4 hours after the last food, which was medium in amount. The subject claimed to be in normal condition and to have taken no alcohol since the previous experiment. The results of the neuro-muscular tests on

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[a] Compare with the effects in the first two hours in series B with *Mow*, Chapter V, p. 185, and see subjective effects reported in Appendix by *Mow*, p. 286.

[b] It is not possible to assign trustworthy ranks to the 6 men in the matter of previous use of alcohol, desirable as this would be for comparing the factor of habituation with our other results. On habituation to alcohol, see Riegel, Psychologische Arbeiten, 1923, 8, p. 48.

[c] His body-weight was 52.7 kg. This is more than 10 kg. less than the other light subject, *Jem*, who weighed 63.1 kg. A high concentration might therefore be predicted for him, and this he demonstrates.

October 14 show a more decided effect of the alcohol than those on October 20, indicating that actually a stronger influence was acting upon his system. These erratic results which *Sut* exhibited in the concentration of alcohol in the blood following doses containing like amounts of alcohol, but with different dilutions, and in the concentration of alcohol in the urine following the same dosage and dilution, together with the reputation that the subject has in reference to large quantities of alcohol, raises the question of abnormality of absorption and elimination in his case.

On one occasion he volunteered the information that he had learned a method which aided him in taking large quantities of alcohol without disastrous results. When he anticipated attending some function where in former times considerable liquor would be served, he fortified himself by drinking 100 or more cubic centimeters of olive oil. He was not familiar with the experimental work that had been done by Hanzlik and Collins (Journ. Pharm. and Exp. Therapeutics, 1913–14, **5**, p. 185) demonstrating retardation in alcohol absorption in ligated intestinal loops when a small amount of olive oil had been injected preceding the alcohol. Undoutedly he had a more extensive alcohol history than any of the others, or perhaps than all of them combined. If comparable data could have been obtained with other subjects with similar experience or of the habitual type, as was our plan, these results would naturally have been presented separately from those obtained with moderate or abstinent subjects. It was not possible to do this, and therefore the experimental results for *Sut* in the foregoing tables of Chapter VI have been presented and averaged with the data for the other men.

The question whether the relative level of the alcohol-urine curve correlates with the general intensity of alcohol effect during the 2 or 3 hours following ingestion may therefore be tentatively answered in the affirmative. That dosage or group of conditions which, contrasted with other experimental series, results in the highest concentration of alcohol in the urine likewise is found to show the most marked general influence of the alcohol on the physiological and psychological processes. Among normal individuals classed as abstinent or moderate drinkers, the height of the alcohol-urine curve gives a fairly reliable index to the intensity of toxic influence which will be demonstrated. These conclusions are perhaps not particularly novel, but, so far as the writer is aware, they have never before been proved by objective evidence. Our data have certain shortcomings and breaks in continuity of which we are quite conscious, but for the conditions tested they give rather definite results. The assumption that a series of urine samples, collected at short intervals, serves as an adequate index of the effective alcohol dosage to which the nervous system is subjected, rests on the supposition that the alcohol enters the urine by way of diffusion. The difference between the alcohol contents of urine and venous-blood samples as simultaneously collected, which is proved by these data, is not necessarily in conflict with the diffusion theory. At present the relationship existing between the alcohol content of urine and of arterial blood is unknown. There is a good reason to suppose that after ingestion the alcohol content of the arterial blood in the unsaturated organism is somewhat higher than that of venous blood. Pending investigation of this biochemical problem, it may tentatively be assumed that frequent urine samples provide a near approximation to the alcohol content of arterial blood and represent the changing course of concentration from hour to hour.

COMPARISON FOR RISING AND FALLING CONCENTRATIONS.

We now turn to a consideration of whether the changing concentration of alcohol in blood or urine which, following a single ingestion, runs a characteristic course of rise and fall, is actually paralleled throughout by changes in the toxic effects. Schweisheimer[a] believed this to be the case. In his excellent paper of 1913 he has a paragraph as follows:

> "A further result for the experimentation is the fact, stated for the first time, that the psychic condition of men who have taken alcohol depends on the concentration of alcohol in the blood. With animal experiments, such a proof could naturally not be given. But in this research, it is absolutely proved that with abstinents, moderate drinkers, and habituals, the condition of intoxication by such signs as dizziness, numbness, tiredness, and, in lighter cases, talkativeness and hilarity, is exactly parallel in increase and decrease with the rising and sinking of the alcohol content in the blood. Aside from this, we have to say that with the abstinent and habitual, the same concentration of alcohol in the blood caused in the first stronger symptoms of drunkenness and in the latter weaker symptoms."

It is not recorded that Schweisheimer made any objective measurements of a physiological or psychological nature to determine the intensity of toxic influence. His subjects were kept in bed during the experiments for the purpose of reducing and making uniform the factor of muscular exercise. His conclusion, so far as the alcohol effect is concerned, seems entirely based on clinical evidence, rather than on measured changes.

In giving the results for the various series of experiments, it has been repeatedly pointed out in this monograph that the maximal influence of the alcohol occurs at about 60 to 90 minutes after ingestion. The charts in Chapters V and VI giving curves for the alcohol effect and the concentration of alcohol in the urine usually indicate[b] that the maximal concentration falls at 60 to 90 minutes. Frequently in presenting these results the intimate connection between the rapid rise in alcohol content of the urine and the prompt and simultaneous fall in the efficiency of the subject has been noted. Considering the complexity of experimental conditions, this phenomenon is so regular and well-marked that it is unnecessary to examine the various series separately. While some measurements, for example, pulse-rate, pursuitmeter performance, and code, do not show the maximal effect so early as knee-jerk and station, yet, as a generalization, our several results demonstrate approximately a parallel temporal relationship between the rising alcohol concentration and the initial falling neuromuscular efficiency with about synchronous maxima for the two processes.

Thus far the relationship outlined agrees well with the statement of Schweisheimer, but when the falling concentration and the decreasing alcohol effect in the second or third hour after ingestion are considered, his conclusion does not fit the facts. An examination of the charts in Chapters V and VI will show that the descending portion of the alcohol concentration curve is much more gradual in slope than is the ascending portion. When, as was usual, the alcohol dose was taken in one portion, the beginning of decline in concentration is observable shortly after the maximum has been reached. The curves do not reveal "the Gréhant plateau"[a] (prolongation of the maximal concentration), probably because the doses were relatively so small as compared with body-weight. With this slow and moderate decline in alcohol content of the urine, there is a rather sudden decrease in the alcohol effect. The amount of recovery far exceeds proportionately the extent of fall. To generalize the findings in another way, a given height on the rising side of the alcohol-urine curve is accompanied by a much stronger measurable effect than is the same concentration-level on the declining side. Rising and falling concentrations may not be equivalent or physiologically comparable as indices for the amount of alcohol acting on the nervous system. Experiments in which the concentration-level after the first swift climb is held steady or made to continue rising very slowly would be of special significance in this connection. Series D, page 187, is of this type. In this series, the subjects took a liter of liquid, 2.75 per cent of which was alcohol; beginning 1 hour later, 50 c. c. doses of the same beverage were taken each 15 minutes for 2½ hours. During this time the alcohol content of the urine very gradually increased. (See fig. 29, p. 189.) The measured alcohol effects, however, show essentially the same results as when the concentration is falling during the latter part of the experiment, i. e., they are much less pronounced. This prominent recovery while the concentration curve in Series D is still rising in the last hour or more of the experimental session is especially noteworthy in the station measurements, but appears also in the data for eye-movement velocity, pursuitmeter operation, and code test.

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[a] Schweisheimer, Deutsch. Arch. f. klin. Med., 1913, 59, p. 271. Patients were given about 1.5 c. c. absolute alcohol per kilogram of body-weight and at various intervals venous blood samples were taken and the alcohol content determined.

[b] Some of the series on *Mow* with 15-minute periods, in which special complicating conditions were introduced, are exceptions.

The pronounced tendency for toxic symptoms to decrease rapidly after the maximal concentration has been reached and before the alcohol content of body fluids has shown much decline was also observed by Mellanby, at first in experiments with dogs[b] and later with men.[c] His conclusions from the work with dogs were in part as follows:

> "A dog begins to show signs of intoxication when the alcohol of the blood reaches about 354 cubic millimeters per 100 grams of blood.[d] At this stage it will probably hit its hind toes against the floor in walking. Its movements will be slower and after a period of excitement its interest in external conditions will be less than usual. This only applies to the ascending portion of the curve. It has already been stated that the symptoms decline after the maximum of the alcohol in the blood has been reached. When the alcohol has declined again to 354 cubic millimeters, the dog will probably appear almost normal, and will certainly be less intoxicated than at the corresponding point on the ascent of the curve."

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[a] Gréhant: Compt. rend. Soc. biol., 1899, 51, p. 946, and 1903, 55, p. 1264.

[b] Mellanby, Alcohol: Its absorption into and disappearance from the blood under different conditions. British Medical Research Committee, Special Rept. Ser. No. 31, 1919, London. See p. 32.

[c] Mellanby, British Journ. Inebriety, 1920, 17, p. 157. In this instance a man was given 171 c. c. absolute alcohol. On one occasion, Mellanby gave 900 c. c. of liquid containing 19 per cent of alcohol by volume and on another 3,100 c. c. of stout, containing 5.5 per cent of alcohol by volume. At intervals after ingestion the subject copied a small drawing of a square, with diagonals, surrounded with a circle.

[d] Equivalent to about 2.84 mg. per cubic centimeter.

In his study of the drawing ability of one man, an habitual, to whom a large dose of alcohol had been given, there was very obvious and rapid improvement closely following the highest concentration in the blood. Mellanby draws the conclusion that descent of the alcohol curve not only means improvement, but "the improvement may be so pronounced that a man may apparently be more sober than on the occasions when less alcohol is present in the blood."

The explanation of this phenomenon is probably not due to any peculiarity of ethyl alcohol as a pharmaceutical substance. It doubtless is to be accounted for on the basis of the irritability characteristics of the nervous system. The rate at which an irritant, such as the electric current, is applied to a nerve is an important factor in initiating the conducted disturbance. This relationship between rate of change and excitation has been long recognized, and in the field of neuro-muscular physiology is known as Du Bois-Reymond's law. On the psychological side similar facts may be abundantly observed for sensory stimulation and adaptation, perception of differences, the shifting of attention, and other mental processes. Apparently the organism is peculiarly susceptible to initial disturbances of its equilibrium. The suddenness with which an irritant or a depressant is applied or invades the body counts much in determining the intensity of the resulting immediate effect.

The influence of alcohol on the physiological and psychological processes thus supplies another instance of the importance of the rate of attack on the nervous system. The dilution or concentration of the beverage, the presence or absence of food in the stomach, the rate of ingestion, the amount of absolute alcohol given per kilogram of body-weight, and other conditions all have their significance in changing the rate as well as the general level and maximal intensity applied to the organism. These considerations emphasize the desirability of making a coincident study of absorption, by some such means as the analysis of urine samples, when measuring the resulting influence from different alcohol dosages.

CHAPTER VIII.

REVIEW AND GENERAL CONCLUSIONS OF INVESTIGATION ON THE INFLUENCE OF ETHYL ALCOHOL.

In the preceding chapters, the conditions pertaining to each series of experiments have been carefully defined, and detailed information given as to alcohol dosage, experimental program and routine, food, etc., even though such statements may appear to some readers as needless repetition. The discussion of results for each measurement has likewise been carried out as if that measure were used in no other series. At the end of each group of experiments a summary of results is given, stating in an orderly way the conclusions which seem justifiable within the limits of that investigation. Thus, each chapter from II to VI, inclusive, is essentially complete within itself as a statement of the influence of ethyl alcohol on neuromuscular processes in man under certain defined experimental conditions. These chapter summaries will not be repeated here, and reference should be made to them in their proper context. A comparison of the various summaries will reveal a striking similarity in at least the qualitative conclusions from the different series of experiments, the results being conspicuously concordant and cumulative. It is this particular feature which will be briefly considered in these general conclusions after a review of certain pertinent facts bearing on the investigation as a whole.

BRIEF SURVEY OF RESEARCHES REPORTED.

This report is based on 166 experiments with human subjects. No experiment was shorter than 2 hours, most of them occupied 3 to 6 hours, and 6 required the services of the subject during the evening, all night, and a portion of the next morning. The observations were made on each subject individually. In 100 experiments a solution of alcohol was given, these being controlled by 66 experiments in which non-alcoholic solutions were ingested. The experiments were grouped as follows:

In a series of 44 experiments, of which 23 were control, i. e., non-alcohol, a study was made of the effect of alcohol on typewriting efficiency and simpler related acts. In the alcohol experiments 21 to 42 grams of alcohol were taken in 14 to 22 per cent (by weight) solutions. The observations were continued for about 4 hours after ingestion of the beverages. Five trained typists served as subjects. (See Chapters II and III.)

Six experiments (three of them control) were characterized by rectal injection of the alcohol, with the subject asleep. In the three alcohol experiments, 37.5 grams of alcohol were given in 7.5 per cent (by weight) solution. The evening and morning performances of the subject were contrasted and the electrocardiogram was studied. (See Chapter IV.)

In 70 experiments with a well-trained subject, 26 of the experiments being control, the alcohol was given in a 2.75 per cent (by weight) solution with various dilutants. The standard dose was 1 liter, containing 27.5 grams of alcohol. The effect was followed for 2 to 4 hours after drinking and a considerable variety of conditions and measurements were studied.

Urine samples were collected at short intervals and the alcohol content determined. (See Chapter V.)

Finally, 46 experiments, of which 14 were control, were made with 9 men, mostly medical students. This study included a comparison of the alcohol content of blood and urine samples when 27.5 grams of alcohol were taken in both a 27.5 per cent solution and a 2.75 per cent solution. The influence of the 2.75 per cent solution upon the physiological and psychological functions was studied and the temporal relations of the alcohol effect with the curves for alcohol concentration in the urine noted. (See Chapter VI.) It is seen from this survey that the great majority of the experiments in the different series have to do with moderate alcohol dosages given in very dilute solutions.

A total of 16 men acted as subjects in the four researches, each man ordinarily serving on 6 or more experimental days. As a general rule, the first two experiments on each subject, although performed with the usual care, were considered as practice, and except for the determinations of the alcohol in the blood and urine samples, the data do not enter directly into the results reported. In one or two instances the men had seemingly been entirely abstinent until the beginning of the experiment, but most of the subjects were occasional moderate users of alcoholic beverages. Two could be classed as habitual, or occasionally immoderate users. Susceptibility to the effects of alcohol was not sought in selecting the subjects, and it is believed that the men represent an average group in this respect. One man, *Sut,* was chosen because of his reputation for showing only slight toxic effects from heavy drinking. None of the subjects gave any evidence of ill health. There was no lack of cooperation on the part of the 16 subjects, but one habitual (not included in this number) refused during the first preliminary day to have a second blood-sample taken, and no further observations were made with him.

In this study of the influence of ethyl alcohol on the human organism, objective data have been collected on about 20 physiological and psychological measurements. Under the physiological measurements may be classed the following: (1) quantitative determination of the alcohol appearing in blood and urine samples at intervals after ingestion; (2) volume of urinary output; (3) metabolic rate as shown by the oxygen consumption; (4) pulse-rate during rest; (5) heart-rate during physical work; (6) the form of the electrocardiogram; (7) the skin temperature; (8) the knee-jerk; and (9) the protective eye-wink reflex. Among the psychological observations, the chief measurements were: (10) reaction time of the eye in turning toward peripheral stimuli; (11) reaction time in speaking exposed words; (12) visual acuity; (13) sensory threshold for electric shock; (14) station, i. e., standing motionless; (15) velocity of eye movement when looking back and forth between two points; (16) speed of finger-tapping; (17) eye-hand coordination with the pursuit pendulum; (18) continuous coordination with the pursuitmeter; (19) typewriting efficiency for tasks of varying difficulty; and (20) transliteration of code material.[a] With several of these measurements, data of more than one sort have been secured, that is, speed and accuracy, quantitative and qualitative phases, or central tendency and deviation have been separately treated.

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[a] The combinations of measurements used in the different series of experiments and the detailed techniques are given in Chapter I.

The individual experiments have usually been divided into half-hour periods. A group of measures which could be completed within this time was carried out twice (periods 1 and 2). Between periods 2 and 3 the alcohol or control solution was taken by the subject and four or more periods, i. e., repetitions of the series of measurements followed this ingestion. Comparison is made between the scores preceding and following ingestion and between the alcohol and non-alcohol groups of days. It is the large variety of measurements as well as the repetition of observations at short intervals for 2 to 4 hours after drinking on any one day which has necessitated so extended a presentation of results in the preceding chapters. It is hoped that the somewhat cumbersome amount of data and the detailed treatment are more than compensated by the ultimate value of a many-sided attack on the problem.

GENERAL CONCLUSIONS FROM EXPERIMENTAL RESULTS.

For a summary of the representative results of the whole investigation. a comparison may be made of the findings with the smaller dose of alcohol (approximately 24 grams) in the typewriting series, the average results in the rectal-feeding series, the averages for the first five series performed on the trained subject, *Mow*, and the averages for the group of subjects who took a 2.75 per cent solution of alcohol. These results are assembled in table 70. The subjects, also the dosages and conditions, were different for each of the four series. The headings for the four columns in table 70 reveal these facts, and the footnotes indicate where the full details may be found. The left-hand portion of the table gives the measurement used and states the general direction of the effect of alcohol demonstrated in the first 2 hours after its ingestion. Except in the column giving the results for rectal feeding, the figures represent averages for the first 2 hours following complete ingestion of the prescribed dose.

By recording the direction of the alcohol effect with each measure, it is possible to eliminate the confusion of plus and minus signs in the percentage results for the effect of alcohol. These statements as to the general direction of the alcohol effect for the period mentioned may be readily verified for any measurement by referring to the several places in the report where the full data for the measure are given. (See Index.)

For the pulse-rate during rest and during work, the metabolism, and the skin temperature, the alcohol effect is in the direction of increase as these factors are usually measured. It will be difficult to challenge the conclusion that these changes represent other than a decrease in organic efficiency due to depressant action of ethyl alcohol, inasmuch as such changes are regularly associated with decreased reflex irritability, slower reaction, less keen, i. e., higher sensory thresholds, slower muscular movements, less adequate and accurate muscular control, and less agile mental operations. The whole qualitative picture is one of decreased human efficiency as a quickly-following result from the ingestion of this pharmacodynamic substance.

One entry in table 70 (1.0 per cent for electrical threshold) is given in italics, as it represents an improvement over normal. In one curious instance,[a] that of the lid-reflex amplitude in the rectal-feeding series, there was no change. The remaining 40 entries in the table are concordant in direction, and when comparisons of the same measure may be made, as, for example, eye movements or finger movements, they show fairly good quantitative agreement between different series. There are 4 cases in which the change produced by alcohol is greater than 20 per cent. These include

TABLE 70.—*Comparison of summarized alcohol effects for various series of experiments.*

[Unless stated to the contrary, the averages cover 2 hours following ingestion of alcohol.]

Measurement.	General direction of alcohol effect in first two hours after ingestion.	Typewriting series, dose A.[1]	Rectal-feeding series, 37.5 gm. alcohol in 7.5 p. ct. solution.[2]	Avg. of 5 series on *Mow*, 27.5 gm. alcohol in 2.75 p. ct. solution.[3]	Group series, 27.5 gm. alcohol in 2.75 p. ct. solution.[4]
		p. ct.	*p. ct.*	*p. ct.*	*p. ct.*
Pulse-rate during rest, rate per min...	Increased.....	5.3	12.0	6.0	8.8
Pulse-rate during work, rate per min..	Increased.....	5.6	8.2	....	....
Metabolism, oxygen consumption....	Increased.....	....	[5]10.0	4.2	....
Skin temperature, face..............	Increased.....	....	....	....	0.5
Skin temperature, hands............	Increased.....	....	....	....	2.2
Patellar reflex, amplitude...........	Decreased....	....	....	....	21.0
Lid reflex, latency..................	Slower.......	4.1	2.2	....	....
Lid reflex, amplitude...............	Decreased....	8.8	0.0	....	....
Eye-reaction time...................	Slower.......	....	2.4	4.4	....
Word-reaction time.................	Slower.......	4.0	....	....	....
Visual acuity.......................	Less keen....	....	4.6	....	....
Electrical threshold sensitivity.......	Less keen....	....	1.9	[6]*1.0*	....
Station, swaying of body...........	Increased.....	....	....	23.4	11.0
Eye-movement velocity (adductive)..	Slower.......	8.3	6.1	6.5	....
Eye-movement velocity (abductive)..	Slower.......	5.9	2.9	5.7	....
Finger-movement speed............	Slower.......	2.8	2.4	1.7	1.4
Coordination for pursuit pendulum...	Less adequate.	....	....	4.7	3.2
Coordination for pursuitmeter.......	Less adequate.	....	....	17.8	14.3
Typewriting, errors.................	Increased.....	39.3	....	....	....
Typewriting, strokes per second.....	Decreased....	2.6	....	....	....
Typewriting, illegibility.............	Increased.....	55.0	....	....	....
Code, letters transliterated	Decreased....	....	....	7.0	2.3

[1] The results used here are from the smaller dose of alcohol given the typewriting subjects. The dose was about 0.5 c. c. alcohol per kilogram of body-weight, hence it ranged from 21 to 28 grams of alcohol and was given in 14 to 22 per cent solutions. See Chapter II.

[2] In the rectal-feeding experiments the effects were measured for 6 to 8 hours after the rectal ingestion of alcohol was begun. See Chapter IV.

[3] See Chapter V, pp. 125 to 180. The studies with 30-minute periods, but not those with 15-minute periods, are included in this summary.

[4] See Chapter VI.

[5] In the 4-hour period following completed ingestion of the alcohol.

[6] Represents an improvement above normal.

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[a] In former alcohol publications from the Nutrition Laboratory, reflex amplitude usually shows marked decrease as an alcohol effect.

the decrease in accuracy and quality of the typewriting performance, the decrease in amplitude of the knee-jerk, and increased swaying in the station test. In 5 instances the change is from 10 to 20 per cent. The measurements which show these prominent alcohol effects are pulse-rate during rest, metabolism, station, and coordination with pursuitmeter. In the range from 5 to 10 per cent there are 12 cases; between 2 and 5 per cent, 15 cases; and for changes less than 2 per cent there are 6 entries.

If all of the experimental series are included, there is a rather large amount of pulse data. These reveal a very definite alcohol effect of an increase in rate, i. e., shortened pulse-cycle length. On control days the pulse-rate usually becomes gradually slower from hour to hour, while after the ingestion of alcohol this retardation is not only lessened but, in addition to this relative acceleration from alcohol, there is frequently an absolutely faster rate than in the preliminary periods before the alcohol was taken. Pulse data were collected with nearly all of the subjects. The singular unanimity of these pulse data is noteworthy when it is remembered that there has been great disagreement in the literature on this point as reviewed by Dodge and Benedict.[a]

In a forthcoming publication by Dr. Thorne M. Carpenter, of the Nutrition Laboratory, pulse-rate will be further considered in connection with the influence of alcohol on the total gaseous metabolism. The results of the present experiments indicate an increased oxygen consumption following alcohol. The pulse-metabolism law, or parallel change of these two functions, thus finds another illustration.

The mechanism by which the skin temperature is increased after alcohol is not revealed by our experiments. It appears reasonable to suppose that it is at least due in part to loss of tone in the peripheral blood-vessels, just as the reflexes have suffered depression of tone resulting in a decreased response and slower action. That some of these phenomena due to the action of alcohol should in the past have been regarded as evidences of stimulation was, perhaps, only natural, but when grouped with the results of other neuro-muscular measurements, the general picture is found to be one of depression and decreased physical and mental efficiency.

In most respects the results of these researches are in substantial agreement with those of Dodge and Benedict, in so far as the former experimenters used comparable conditions and dosages. From the data gathered in the researches reported in this monograph, it would seem necessary to dissent from one of their conclusions, or at least to consider that the generalization should be held in abeyance. In discussing the effects of alcohol on the different levels of the nervous system, they state: "The lower centers are depressed most and the highest least."[b] If their summary in table 46 (p. 244 of their report) is taken as it stands and the figures are read from left to right as representing lower to higher centers, it is seen that their conclusion is largely influenced by the marked alcohol effect on the amplitudes (H) of the two reflexes included in the group of measurements. If the comparison is confined to the time factor or latency (R) of the reflexes, since it is the time factor that is under consideration for the reactions and the coordinations, there is but little distinction and the generalization is unsupported.

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[a] Dodge and Benedict, Carnegie Inst. Wash. Pub. No. 232, 1915, pp. 186 et seq.

[b] *Ibid.*, p. 245.

Similarly, in table 70 of the present monograph, when the depressant effects of alcohol on the rates of different processes are compared, it is found that the influence upon reflex latency is 4.1 and 2.2 per cent, on reaction time 4.0, 2.4, and 4.4 per cent, on velocity of eye movement a general average depression of about 6 per cent, on speed of finger movement about 2 per cent, on coordination with the pursuit pendulum 4.7 and 3.2 per cent, on the rate of typewriting 2.6 per cent, and on the rate of transliterating code 7.0 and 2.3 per cent. Without affirming that all levels are influenced equally, we may conclude that at present there is no certain evidence that in general the higher centers are influenced least.

Reflex amplitudes are conspicuously variable measurements,[a] and unless one can compare them with some equally variable phenomena at the higher neural levels, quantitative comparisons are likely to be somewhat unbalanced. In making use of any neural process for the study of such an ingested substance as alcohol, much depends on the particular factor selected for observation. If, for illustration, the process being measured is typewriting, and we consider the rate of striking the keys, the effect is found to be approximately 3 per cent. If, however, we choose to observe the frequency of striking wrong keys, then the alcohol effect is above 30 per cent. Again, if we select a still more variable or accidental phase of the process, viz, sequent combinations of errors which result in illegibility of the copy, then the alcohol effect is above 50 per cent. The factors in any neuro-muscular process which are normally quite variable seem also, as a usual thing, quite vulnerable to the attack of alcohol. The adequacy or quality of work, at least in laboratory performances, suffers more under alcohol than does the quantity or rate of work. Any assessment of the decreased efficiency resulting from small amounts of dilute alcohol must take into account both these phases. It is much the easier to measure accurately the speed factor. This in our experiments shows a value approximating a 5 per cent decrease as an average for the several instances in table 70. Judging from the errors in typewriting and from the decreased accuracy in coordination with the pursuitmeter, the quality of work suffered by about 20 per cent.

There is no longer room for doubt in reference to the toxic action of alcoholic beverages as weak as 2.75 per cent by weight. If 27.5 grams of alcohol are taken in this form, the well-defined and measurable depression in physical and mental processes, judged within the limits of this investigation, is not far short of the result found when 21 to 28 grams of alcohol are taken in solutions varying from 14 to 22 per cent.

Alcoholic beverages of all strengths may be taken so slowly, in such small amounts, or so diluted with food that the content in the blood remains very low and the effects likewise minimal. For the influence on the alcohol effect of such factors as dilution of beverage, size of dose, rate of ingestion and absorption, food, habituation to experimental routine, the effort of men to resist the alcohol effect in their laboratory performances, body-weight, individual differences in susceptibility, etc., the reader must be referred to the summaries in previous chapters.

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[a] In another connection (see Benedict, Miles, Roth, and Smith, Carnegie Inst. Wash. Pub. No. 280, 1919, pp. 592–593), the writer has reported knee-jerk data collected on 63 men. Of this number, 15 did not show a reflex of measurable amplitude; the remaining 48 men gave an average of 15 mm., with a range of 2 to 45 mm. The standard deviation for the entire series was 11.4 mm. and the coefficient of variability 76 per cent. The coefficient of variability for the reflex latencies was, however, 21 per cent, which is approximately that found for reaction time measurements.

APPENDIX.

SUBJECTIVE EFFECTS OF ALCOHOL.

The presentation and discussion of the results in the preceding chapters have been strictly objective in character. These results were apparatus readings of one sort and another, uninterpreted and unsupplemented by any subjective impressions of either the men experimented upon or the experimenter. Such quantitative evidence and impersonal treatment are required for the problem considered in this report.

The subjective side of the question must not, however, be wholly neglected if we are interested in the psychological influence of ethyl alcohol. The man experimented upon is continually required to respond promptly and accurately to various tasks. Obviously he will have subjective impressions of his fitness for carrying out the routine demanded of him and will form judgments as to the satisfactoriness of his performance. If there are any unusual sensations, it is he who knows their qualitative aspects. These personal sensations and opinions are very important to the individual and influence the working capacity. It has often been incidentally reported, when moderate doses of alcohol are used with human adults, that the subject's impressions concerning his own efficiency ran counter to the objective results.[a] Furthermore, such observations will have interest, since it has been noted in the previous discussion that the objective results for various men show effects from the ingestion of the alcohol which are definitely in the same direction, and it is reasonable to suppose that there will be similar uniformity in the subjective impressions of the men.

In view of these considerations, it seems justifiable to give here summaries of personal observations and impressions which were recorded at the time of the experiments in the series discussed in Chapters II, III, V, and VI, i. e., the experiments with typewriting, with the trained subject *Mow* with very dilute alcohol, and with the group of men likewise studied after doses of very dilute alcohol. These should have significance to the reader in answering various questions having to do with alcohol experimentation, as, for example: (1) Is a liter of fluid too much to take at one time? (2) Can the alcohol in the dose be so masked that the subject is unaware of its presence? (3) At what time after drinking are the subjective effects most prominent? (4) Under what circumstances are the effects most clearly recognized, and how are they generally described? (5) Do most of the subjects feel aided or hindered in their laboratory routine work by the effects experienced? (6) Do the men exhibit distinct individual differences?

TYPEWRITING EXPERIMENTS.

Typewriting belongs to a group of skilled operations, in which the accustomed operator has a unique chance to judge his own efficiency, particularly when the typist rewrites the same or similar material from experiment to experiment. For this reason the general introspections of the subjects of the typewriting experiments should be of unusual interest.

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[a] In the recent study by Meyer (Am. Journ. Psychol., 1923, 34, p. 501), alcohol doses of 10 c. c. were used in a study of the effect of alcohol on writing shorthand. He observes (p. 509): "the work of the alcohol days seemed to fly ahead and pull the operator after it. And then, when he looked at the outcome, he found to his surprise that his efficiency was much poorer than he had expected. It seems clear that a worker who lacks means of objectively measuring his efficiency can not trust his own feelings in the matter." See, also, a new study of the effect of alcohol on perception, Roos, Psychologische Arbeiten, 1923, 8, p. 93.

At the close of each day's experiment, every typist was asked to give his impressions concerning his own work and the effects of the dose. The subject never knew how much alcohol was taken, but believed that the dose always contained alcohol. The men were not questioned on a set list of topics, as their own descriptions of personal experiences were desired. Some naturally expressed themselves more freely than others, following and during the experiment. In addition to these notes, the investigator had ample opportunity to make full records of the comments and behavior of the men while they were engaged in typing. Excerpts from these notes as to the subjective effects of the alcohol are given in the following pages.[*]

Roj (I).

September 21, 1914. Control dose at $11^{h}20^{m}$ a.m., 4¼ hours after food.

"Felt no effects from medicine; it tasted like cloves."

September 22, 1914. Alcohol, dose A, 24 gm., at $10^{h}25^{m}$ a.m., 3¼ hours after food.

"The type bars seemed to lock and interrupt my writing with unusual frequency to-day."

September 23, 1914. Control dose at $9^{h}45^{m}$ a.m., 2½ hours after food.

"The dose to-day was not so strong as yesterday, but stronger than on the 21st."

September 24, 1914. Alcohol, dose A, 24 gm., at $9^{h}40^{m}$ a.m., 3 hours after last food. $10^{h}55^{m}$, practice No. 4, subject acted fatigued and sleepy.

"I felt a little dizzy after taking the dose. Really it is the first time that I have felt or seemed to notice it. It caused me to yawn a few times."

September 25, 1914. Control dose at $9^{h}45^{m}$ a.m., 2¾ hours after food.

"To-day I felt unable to make my fingers work. My arms became more tired than usual. I got some relief by holding them in against my sides. I did not notice the medicine, or the effect of it very much, unless it was this tiredness in my arms."

September 26, 1914. Alcohol, dose B, 35 gm., at $9^{h}40^{m}$ a.m., 2½ hours after food. $10^{h}34^{m}$, nonsense copy No. 3, subject missed the carriage handle and hesitated once in the middle of the movement.

"This morning's dose affected my legs and made me feel weak and drowsy, something like my experience the day before yesterday (September 24). My arms did not feel as they did yesterday. To-day when I tried to make speed, it seemed as if I would strike two keys instead of one, that is, my fingers would strike in between the keys. I think the dose was stronger, perhaps, than on any other day, and affected me fully as much and maybe more. Usually my work in the second period is better than in the first, and in the third period it is the best of all during the day. This morning during the second period I felt lost."

Roj (II).

October 5, 1914. Control dose at $9^{h}05^{m}$ a.m., 2¾ hours after food.

"No effect was felt from the medicine."

October 6, 1914. Alcohol, dose A, 24 gm., $8^{h}45^{m}$ a.m., 2 hours after food. At $8^{h}50^{m}$ he seemed to be writing much faster than during the first period. At $9^{h}50^{m}$, sense copy No. 4, he leaned far back in his chair as he worked, evidently trying to ease up some condition that was troubling him.

"My eyes grew very tired. They almost watered for a while this morning. I think these things were the effect of the medicine. About $10^{h}00^{m}$ I was so tired I would like to have been excused for the day."

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[*] Comparison of these notes with the experimental records may be made by reference to Chapters II and III, pp. 29 to 110, and more especially to tables 1 to 33, inclusive.

October 7, 1914. Alcohol, dose B, 35 gm., 8^h50^m a.m., 2 hours after food. 9^h19^m, practice No. 3, subject had a great deal of trouble with the locking of the keys. 10^h18^m, subject excused for urination.

"To-day was much harder than yesterday. The drink seemed to take the life and snap right out of me; I could not help it. I was drowsy and my fingers seemed to be stiffened, making it impossible to strike the keys that I wanted. My lower limbs did not seem affected as at some other times."

October 8, 1914. Control dose, 8^h45^m a.m., 2 hours after food.

"The medicine to-day produced no effect that I could feel. I did not get tired; once or twice my fingers felt slightly tired from work, but there was not the characteristic effect of the medicine. The work was much easier than yesterday."

Lig.

September 28, 1914. Control dose at 11^h50^m a.m., 4½ hours after food. He had no trouble with the type-bars catching, and seemed to get on very well.

"I felt no effect from the drink, but was a little nervous because of the newness of the work. Some of the inaccuracy in my work was because of trying for speed."

September 29, 1914. Alcohol, dose A, 24 gm., at 10^h00^m a.m., 3 hours after food. 10^h17^m, nonsense copy No. 2, he shook his head several times as if he recognized having made mistakes. 11^h00^m, subject excused for urination.

"I think I could feel just a little effect of the 'dope.' It seemed to make me feel free or happy. I do not think that it hindered my work. Are you going to increase the dose at the same rate or in the same proportion as to-day's increase over yesterday's dose?"

September 30, 1914. Control dose at 9^h05^m a.m., 2¼ hours after food.

"No effects of the medicine, only the effects of increasing tiredness."

October 1, 1914. Alcohol, dose A, 24 gm., at 8^h50^m a.m., 2 hours after food. 9^h55^m, subject excused for urination.

"No particular effect of the drink except a kind of warming in my stomach. My eyesight not so good as usual. I feel decidedly better now than at the end of the work yesterday."

October 2, 1914. Alcohol, dose B, 35 gm., at 8^h45^m a.m., 2 hours after food. 9^h50^m, subject excused for urination. Many times during the day the subject shook his head, as if he had trouble in finding the right key, or had already made a mistake. This was especially when he was working with the nonsense copy.

"I am tired, more tired to-day than after the work yesterday. I was not tired to begin with, though. It seemed to me to be a hard day all through. I have not been able to make the typewriter go so well as at other times. Thought of asking to be excused to plunge my face into cold water to wake me up. I thought, however, that this might not be in harmony with your experimental procedure. I have some headache now, but do not know what caused it; I did not have it to start with."

On the following day, October 3, before beginning experimentation, *Lig* had the following comments to make regarding his experience on October 2.

"After I came out of the sleepiness or doze which I felt during yesterday's experiment, I was somewhat sick, my head began to ache, as I told you, and I felt a little nausea."

October 3, 1914. Control dose at 9^h10^m a.m., 2½ hours after food. Subject had a little tendency to diarrhea. 12^h27^m p.m., nonsense copy No. 8, he made a fumble at some place in his copy to such an extent that he said "Oh," upon discovering his mistake.

"Noticed no effect of the drink to-day. My work was satisfactory to myself this morning."

Suf.

November 2, 1914. Control dose at 11^h10^m a.m., 3¾ hours after food.

"Felt no effects of the medicine, but somewhat nervous in the midst of so much apparatus."

November 3, 1914. Alcohol, dose A, 24 gm., at 9h45m a.m., 2½ hours after food.

"The alcohol made me a little dizzy at first. Perhaps it caused me to work somewhat faster, but I may have made more mistakes."

November 4, 1914. Control dose at 8h50m a.m., 2½ hours after food.

"To-day I had no difficulties; there was no effect of the medicine experienced."

November 5, 1914. Alcohol, dose A, 24 gm., at 8h35m a.m., 1¾ hours after food.

"I got along very well in the experiments, but the drink made me feel somewhat dizzy or light-headed, as on the second day of the experiments. I think I worked faster as a result of the medicine.[a] The light-headedness does not last throughout one whole set, but continues for only about 15 minutes. At other times, when I have taken liquor of my own accord, I have experienced much more dizziness and light-headedness than I have so far felt in these experiments, so I can easily recognize the effects."

November 6, 1914. Alcohol, dose B, 35 gm., at 8h50m a.m., 2¼ hours after food. 9h55m, he was excused for urination.

"The drink affected me about as it did yesterday, and I think helped me to make speed as usual.[a] It helped me to get down to business. I am not at all tired. My finger movements to-day were not so good as on other days. When I tried to move my fingers as rapidly as possible to-day, they seemed to cramp along at the end of the second period. This I have not noticed before."

November 7, 1914. Control dose at 8h45m a.m., 2 hours after food.

"I noticed no effects from the dose to-day. My fingers did not cramp as I spoke of their doing yesterday."

Fam. (I).

March 22, 1915. Control dose at 8h20m p.m., 1¾ hours after food.

"I did not taste the alcohol; it was hidden by the taste of orange. My fingers seemed to get crossed a good many times. I think this was due to the medicine."

March 23, 1915. Alcohol, dose A, 21 gm., at 7h46m p.m., 1¼ hours after food. 8h30m, he could not remember what came next, and had to be reminded that the practice material and not the sense copy was to be written at this time.

"The drink made me a little sleepy this evening. I could taste the alcohol more than last night, and think it affected me more to-night."

March 24, 1915. Control dose at 7h10m p.m., ¾ hour after food. He expressed certainty that the drink contained alcohol.

"I got on pretty well with the work, except that the drink made me sleepy at the beginning of the third period and continued through the fourth. During the last two periods I felt some better."

March 25, 1915. Alcohol, dose A, 21 gm., at 7h20m p.m., ¾ hour after food. At 8h22m, during the word-reaction test, the subject seemed depressed. 9h57m, just before the nonsense copy No. 6, subject was given a glass of water, as on the previous night and at the same place in the experimental program.

7h45m, "My breathing is quite unnatural. I feel just like crawling out on the floor and going to sleep." End of session: "I could not make my fingers go. I was sleepy, numb, and 'dopy.' I wanted to lie down. But in the last three periods this feeling left me completely and I was able to do good work."

March 26, 1915. Alcohol, dose B, 32 gm., at 7h15m p.m., ¾ hour after food. At 7h55m, sense copy No. 3, he was writing very fast. The keys locked together frequently. He was very evidently fighting the effects of the dose.

Following experiment: "I was rather sleepy during periods 5, 6, and 7, but did not have so much of a sleepy, 'dopy' feeling as I did last night. I tasted the alcohol as much and, I think, more than before."

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[a] These subjective impressions of *Suf's* work may be compared with the objective results in tables 3, 5, and 7, pp. 49, 54, and 58. In the first table mentioned, it will be found that he did actually write more strokes per second in the practice task in periods after dose B. After dose A he did about as well in period 2, and better in periods 3 and 4 than found in the preliminary period. With the prose copy he surpassed his preliminary performance only in period 2 after dose B. With the nonsense copy (table 7), his speed performance was always slower after the alcohol. Therefore it was the work with the practice sentence that gave the subject his impression, which, as a whole, was not borne out by the data.

On the following evening (March 27), before beginning the tests, the subject as usual made statements as to his physical condition, food, amount of sleep, and other conditions, and then entirely without solicitation or questioning made these comments:

> "Last night, after I left here, I was very unusually tired, more tired than at any time during the week. I wanted to go to sleep in the car. During the experiment I had the idea of getting through on time and of doing the same amount of work as on the previous night, and this seemed to keep me up until I got through and went away from the Laboratory. Then there came a relapse and I felt especially tired."

He made no remarks to indicate that the dose had been unusually large. When asked if he thought he could really judge of the effect of the alcohol doses on his own typewriting performance, he answered:

> "Well, if you want to know in so many words—the alcohol slows me down; at least, the way we are taking it here. The effects are most noticeable from the beginning of the third period on to almost through the fifth period, and then they practically go away. That is my experience. I came to this conclusion about the third night, and did not have this idea before engaging in the experiments. It is an observation on my own work."

No confirmatory or direct reply was made. He commented further:

> "If I could take the alcohol and then go out of doors and walk for an hour or so in the open air and come back, I believe that I would feel hardly any effects, but to take it and then plunge right into the work, I am quite sure that the effects will show up and rather prominently."

March 27, 1915. Control dose at 7h18m p.m., ¾ hour after food. On beginning to drink, he said:

> "I can smell it. Could taste the alcohol but very little and there was no belching tonight. Felt myself slowed down in the nonsense copy, but can not remember in what period."

Fam (II).

June 9, 1915. Control dose at 6h25m p.m., 3¼ hours after food. From the beginning of the first period it was evident that he was not working to his usual capacity. He admitted having lost sleep by very late hours the previous two nights and was dismissed.

June 10, 1915. Control dose at 6h15m p.m., 3 hours after food. The subject had no symptoms of sleepiness tonight.

> "No effects this evening and not drowsy."

June 11, 1915. Alcohol, dose A, 21 gm., at 6h05m p.m., 3 hours after food. 6h10m, practice No. 2, appeared to be the fastest he had ever shown in the tests. 6h43m, he belched frequently. 7h48m, sense copy No. 5, he was evidently trying very hard for speed.

> 6h14m. "I can taste the drink all right." 6h43m. "I am having to force myself at the last of the second period and now I feel something of that 'dopy' sensation. My arms feel heavy and numb." Following the experiment: "In the third and fourth cycles I forced myself to keep up the speed in spite of the effect of the dose."

June 12, 1915. Alcohol, dose B, 32 gm., at 5h25m p.m., 2¾ hours after food. After he had taken the dose he made a grimace and asked if he could not have a little water to take the taste from his mouth; he was given 20 c. c. of tap-water. 6h40m, subject was quite talkative.

> 6h30m, sense copy No. 4. "We are almost half through and it seems as if we had not been working very long. I am not making many errors, except on that word 'brave.' I can not get the 'r' quickly enough." Following the experiment: "There was a sensation of heaviness in my arms in the last part of the second and the first part of the third periods. I think I did not make so good speed as last night."

June 13, 1915. Control dose at 5h25m p.m., 2¾ hours after food.

> 6h50m, practice No. 5. "For speed and accuracy, this practice sheet is about the best I have made in the whole series." At the end: "Did not have any of the burning in my stomach that I had on the previous night. The medicine is

hard to take. I do not think it will start me on the road to drinking again. To-night I felt a little below par in the fourth period for some reason."

Mih (I).

April 19, 1915. Control dose at 7^h15^m p.m., 1¼ hours after food. Following the experiment, the subject gave no account of any alcohol effect, nor did he indicate whether he thought the dose contained much or little alcohol.

April 20, 1915. Alcohol, dose A, 26 gm., at 6^h45^m p.m., ¾ hour after food. 6^h58^m, he forgot that he was to write the nonsense copy and immediately after the sense copy, he started to come across the room for the word-reaction experiment. 8^h07^m, nonsense copy No. 4, subject, in throwing back the carriage, missed the lever very frequently at the first attempt. (The form of the lever was not identical with that he uses in the business office.)

"Do not think that the dose affected me. I belched a very little, perhaps twice, but did not experience any sleepiness."

April 21, 1915. Control dose at 6^h20^m p.m., ¾ hour after food. 7^h04^m, subject lost his place completely in nonsense copy No. 3.

Following the experiment: "I am not tired or sleepy, and did not feel any effects of the drink."

April 22, 1915. Alcohol, dose A, 28 gm., at 6^h25^m p.m., ¾ hour after food.

"I felt no effects whatever this evening. There was no discomfort in the stomach and no dizziness. The work seemed to progress very nicely."

April 23, 1915. Alcohol, dose B, 42 gm., at 6^h20^m p.m., ¾ hour after food.

"I have just a touch of headache. Sometimes after taking the drink I could hardly move my fingers, especially in the finger-movement test. Near the end I felt a slight burning in the stomach."

April 24, 1915. Control dose at 6^h25^m p.m., ¾ hour after food.

"I thought the medicine affected me a little this evening in the second and third periods. My fingers seemed limp and I was a little drowsy and dull, then everything came back to me in fine shape in the fifth period. I did not belch nearly so much to-night as last night. As a general thing in these experiments I have felt no effects of the medicine or practically none. I smelled and tasted the alcohol and have belched some, but that is about all."

Mih (II).

June 21, 1915. Control dose at 6^h10^m p.m., 5¾ hours after food. From the remarks of the subject after the experiment, he evidently experienced no effects this evening.

June 22, 1915. Control dose at 5^h55^m p.m., 5½ hours after food.

"I have not felt sleepy during the evening and was not influenced in any way by the drink."

June 23, 1915. Alcohol, dose A, 28 gm., at 5^h55^m p.m., 5½ hours after food. 6^h05^m, sense copy No. 2, subject did not write so fast as in the first period. Immediately after the sense copy, he made ready for the word-reaction test, forgetting the nonsense typewriting. When he was told that it was not time for the word reactions he did not seem to understand without very full explanation. He walked very unsteadily, giving definite evidence of intoxication. He recognized the condition himself and seemed somewhat embarrassed.

"I noticed myself feeling topheavy in the middle of the second period, and when I got up to begin the word-reaction test, before the nonsense copy had been written, my legs felt queer, as if in walking I was lifting them up too high in the air for normal steps. I hardly knew what I was sent back for at first, until I came to my chair and then remembered that I had not written the nonsense copy. I did not feel natural until the fifth or sixth period. In the middle of the second sense copy I had to get my head near to the page to see the copy. I could not be so sure of the words as previously."

June 24, 1915. Alcohol, dose B, 42 gm., at 5^h50^m p.m., 5½ hours after food. 5^h55^m, practice No. 2, a very good typewriting performance. 6^h05^m, nonsense copy No. 2, he appeared to be having a very difficult time. His breathing was labored and he leaned forward near the copy, although the lamp was adjusted as usual. Unstable in his movements when walking over to the word-reaction position. On returning to the typewriter at the beginning of the third period, he was in poor condition for work. 6^h22^m, sense copy No. 3, face almost in contact with the copy at times. He looked over the top of his glasses as elderly persons often do. 8^h00^m, period 6, the work was very satisfactory.

Following the experiment: "The alcohol acted on me the same this evening as it did last night. I was not sleepy and had no headache, but simply felt a kind of hazy condition. It is all gone now. I think the drink did not taste quite so strong as last night, and perhaps did not give me such a burning feeling in my stomach."

June 25, 1915. Control dose at 5^h48^m p.m., 5½ hours after food. 6^h15^m, practice No. 3, he did fast work and showed none of the signs of distress exhibited the previous night.

"I experienced none of the feelings of the previous two nights. There is no one period that I can designate as poorer in its production than the others this evening. To-night it tasted more like medicine; on the previous two nights it seemed to taste more like whisky. The doses had more effect on me the two preceding nights than in the first series of experiments."

From the foregoing notes and comments, it is perfectly evident that the complete masking of the alcohol in such experiments is practically an impossibility. Doses compounded so as to resemble "bitter medicine" more than usual beverages make it difficult to estimate the alcohol content at the actual time of ingestion, but the masking of the substance from taste is unimportant unless the doses are exceedingly small. The experiences of these men prove that if 25 grams or over are given on a relatively empty stomach, there are characteristic subjective symptoms which are clearly recognizable.

There were 22 experiments[a] in which the non-alcoholic control dose was given. In 16 of these, the subjects reported that no effects were experienced. On six occasions, September 23 and 25 (*Roj* I), March 22, 24, and 27 (*Fam* I), and April 24 (*Mih* I), the men thought the dose produced some effects, but these are reported as mild. The reports made by *Fam* and *Mih* were for experiments in their first series, which immediately followed a heavy meal taken at the Laboratory. The dullness may have resulted from the proximity of the meal. Of the 13 occasions when dose A was given, two are reported as having "no effect"; these were in the first series with *Mih* after the Laboratory meal. Four were stated as giving mild effects, six as clearly recognizable, and one (*Mih* II, June 23, 1915) as very strong. After dose B, which was given eight times, there was one experiment (*Mih* I following food, April 23, 1915) in which the effects may perhaps be characterized as mild. In all the other seven cases the alcoholic influence was prominently present to the men.

Although ignorant of our dosage routine and that non-alcoholic control doses were given, the men regularly reported subjective symptoms which distinguish between the control and alcoholic beverages. When alcohol was actually given, they usually recognized a diminution in their own typing efficiency, so that, in general, the subjective impressions agree with the objective results. The subjects as a rule tried to resist the effect of the alcohol and to keep up their rate of work. This fact has a bearing on the interpretation of the results obtained in most laboratory experiments with alcohol.

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[a] Excluding that of June 9, 1915 (*Fam* II).

EXPERIMENTS ON MOW WITH DILUTE ALCOHOL.

The author personally served as subject in all the experiments chronologically outlined in table 37, page 130, which are discussed in Chapter V. In addition to the objective records, the subject (designated as *Mow*) made personal notes regarding his sensations and impressions in connection with the experiments. These notes were entirely spontaneous, recorded without thought of publication, and usually written immediately after the laboratory sessions, or, at latest, the evening of the same day or the following morning. The notes are rather fragmentary and not to be considered a complete introspective analysis. They were made with no knowledge of the experimental records, and the writer believes his notes to be quite independent of suggestion from other people and free from an attempt to accentuate any factors in the subjective experience. As notes for the numerous observations on *Mow* were more or less similar in character, it has seemed desirable to condense them to a summary rather than to follow the detailed presentation adopted for the typewriting experiments and those subsequently given for the group of men.

It will be remembered that the conditions varied considerably in the series with *Mow,* more particularly in the experiments with the shorter periods (15 minutes). The subjective impressions are therefore not grouped chronologically, but according to the conditions, those for standard conditions being given first. Under standard conditions the 27.5 grams of alcohol, diluted to a volume of 1,000 c. c., were given in a single dose at the end of the second period. In referring to the various experiments, the numbers given correspond to those in the chronological table 37 on page 130.[a]

Water or grape juice was used for combination with the alcohol, except for two series in which beer and cider were employed as dilutants. *Mow* found the grape-juice combination easier to take than any of the others. as the taste of the raw alcohol was less noticeable. He could easily smell and taste the alcohol and noted definitely different sensations in the mucous membrane of the mouth and throat after it. (Experiment No. 4.) "The beverage seems especially unpleasant as one finishes taking a glass of it. During the actual moments of drinking it is not distasteful."

Within 15 minutes of taking the dose, slight dizziness was usually felt, with sensations of fullness and dullness in the back and sides of the head. There was a feeling of lack of control, with instability and limpness of knees, especially apparent in any major change of position, such as from sitting to standing, in walking, and particularly in changing his direction in walking. When sitting quietly, this lack of control was hardly noticeable. (Experiment No. 3.) "About 30 minutes after ingestion and for a period of one-half hour or more a strange feeling in the lower limbs persisted. This resembled that which occurs when, after a long bicycle ride, one dismounts and starts walking." (Experiment No. 43.) "At the drinking of the first glass a slight sensation of fullness passes over the back of the head. This is combined with a little indefiniteness or blurring of vision. Later the fullness and dullness in the back and sides of the head become more pronounced. One yawns at intervals and stretches the arms. About 30 minutes after such doses of alcohol as I am taking the knees feel limber, not weakened, but unsteady. On quickly turning and rising to walk there is some uncertainty in the action of the legs and feet and also in the eyes. Possibly it is the compensatory eye movements that are disturbed." At the end of an experiment (2 to 3½ hours), these effects had largely or wholly passed away. In the standing test, *Mow* noted at times sudden variations from vertical greater than usual.

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[a] Comparison of these notes with the experimental data may be made by reference to tables 38 to 53 for the experiments with 30-minute periods, and to figures 26 to 36 for the experiments with 15-minute periods, all in Chapter V.

After taking the liter of alcohol or control solution, the subject noted a distinct cooling of the body, particularly in the hands and arms. He would usually lean against a steam radiator during the 5-minute interval after the complete ingestion of the dose.

In addition to these physical sensations, there was also (experiment No. 33) "a feeling of remoteness, of not being in intimate contact with the work in hand. When I make some adjustment in preparation for one of the experimental tasks, I keep assuring myself with such phrases as the following: 'Yes, it is correct'; 'I have fixed that in the right way'; 'I have not forgotten it,' etc. A part of this is of course due to my concern that the experiment shall be uniform in all of the adjustments." (Experiment No. 3.) "Some 30 minutes after drinking the dose, a minor matter of repair had to be made on the falling-plate camera used to record the eye movements, and I attempted to assist the technician in this matter. It seemed to me that I could do my part all right and that I succeeded in it, but I was conscious of working at long range or as if under distracting conditions."

In his notes for experiment No. 47, he says: "Although I have not mentioned association and mental imagery following alcohol in my earlier notes, because it seemed that these phases might easily be modified by some mental attitude, I am quite confident now that there is a change in these produced by such alcohol doses as I have been taking. The 5-minute performance at the pursuitmeter has become fairly automatic, so that the attention often wanders. I notice frequently during the interval mental associations for which I can not trace the connection. These come so suddenly, and with such a warm glow and persistent vividness, that I am surprised. One feels his experiences are very rich and important. The most agreeable results from my taking the quantities of alcohol common in these experiments is this rich and warm mental association stream, and second, the fact that the experiment passes more quickly and the routine seems less tedious after alcohol."

(Experiment No. 62.) "During this experiment I have again noticed the vividness of mental images from memories of all sorts. They stand out sharply, nearly like perceptions. One cause for this may be that after alcohol I am not so apt to be distracted by noises about the building or other sensory stimulation. This, coupled with the chance nature of the associations which come as distinct surprises, makes it easy for one to give himself up to an unusual degree to the enjoyment of this mental reverie."

Mow estimates his efficiency in the various tests in his notes for experiment No. 33. "With the code test I usually feel that I do better with the alcohol. The letters for substitution seem to come easier and I can at times get two in rapid succession. I feel sure that the letters are being written as I want them written and think T, I, J, Q, F, H, U, V, and Y are made somewhat more promptly than the others. Previously there has been some difficulty in making the letters quickly and at the same time plainly. Under normal conditions I now occasionally experience an inhibition when I wish to write J, I, H, or F, but after alcohol I do not have this hesitation."

"The eye movements and eye-reaction measurements seem much the same after alcohol as under normal conditions. These two tests are the easiest of all and are done without appreciable effort on my part. In the finger movements I seem to be as rapid with alcohol as without, but note that I can not make a free large amplitude so easily. My fingers seem cramped and to require more effort to move them. When I sit down at the pursuitmeter, I feel it will be possible for me to do as well as without the alcohol, but sometimes during the 5-minute test I notice, to my surprise, that the needle has wandered farther to one side than I usually allow it to do. With the pursuit pendulum there is hardly any difference, except that the test seems to be carried out more easily after alcohol. In the station test I can not stand quite so still after alcohol. With the electrical threshold I believe I do as well with the alcohol as without it."

In experiments Nos. 38 and 41, the beverage contained more alcohol than the standard dose. This was not known to the technician and the subject at the time of the experiments, as the alcohol content of the cider used as a dilutant had increased more rapidly than was predicted. The subject, however, noted a difference in the effects. (Experiment No. 38.) "The effects throughout the afternoon were stronger than usual." (Experiment No. 41.) "I felt the subjective effects more strongly than usual, but not so strongly as in experiment No. 38." The dose in experiment No. 38 contained 34 grams of alcohol and that in experiment No. 41 contained 28.8 grams instead of the 27.5 grams of the standard dose."

Beginning with experiment No. 43, the periods of measurement were shortened from 30 minutes to 15 minutes, and the length of the experiments extended. Nearly all of the short-period experiments varied in some way from the standard conditions, and such subjective impressions as are of interest will therefore be grouped according to the series.

Series A.—The experiments (Nos. 43 and 58) were made under standard conditions and the subjective effects have already been cited.

Series B.—Subject post-absorptive, otherwise standard conditions. (Experiment No. 52.) "Noticed no change in subjective symptoms. Urine samples not large, and passed without difficulty." (Experiment No. 54.) "Subjective effects continued longer than usual, even to the end of period 16. About the sixth period they seemed to clear away somewhat, but later the symptoms increased in strength."

Series C.—Standard dose divided into three parts (333 c. c. each) and taken at the beginning of periods 3, 5, and 7. (Experiment No. 59.) "During periods 8, 9, and 10 I noted subjective effects which seemed nearly as strong as those noted with standard conditions. Urination not difficult until the quantity suddenly decreased in the last three periods." (Experiment No. 61.) "Effects experienced not at all strong. Urine at the last of the session passed only with difficulty."

Series D.—Standard dose, with additional 500 c. c. taken in 10 portions of 50 c. c. each at the beginning of each period from periods 7 to 16 inclusive. (Experiment No. 63.) "I noticed an increase in the subjective effects over those experienced when only 1 liter has been taken. Nearly normal in periods 15 and 16."

Series E.—Standard dose, followed by an additional 900 c. c. taken in nine portions of 100 c. c. each, at the beginning of each period from periods 8 to 16 inclusive. (Experiment No. 60.) "To-day the subjective effects seem stronger than usual, especially at first, and this continued through period 7. I have no explanation unless the heavy physical work of the previous day made me more sensitive. The quantities of urine were large even from the beginning. Headache began near the end of the experiment and I was uncomfortable during the evening. The symptoms did not clear away until about 9 p.m." (Experiment No. 62.) "Following the ingestion of the standard dose, I noted fairly strong effects, which increased. As I write these notes (4 hours later), I feel the influence as strongly as at first, this being particularly observable when I move and even as I sit writing. There is a dull, heavy feeling about the eyes and a desire to lean heavily on the desk before me. I feel confident of my ability to do anything of a routine nature." Mental images and memories vivid in this experiment. (See earlier notes for standard conditions.) The following morning he states: "Had dull headache in evening and quite disinclined to work. The experience was very different from that of the usual experiment."

Series F.—Double dose, 2,000 c. c. taken within 20 minutes. (Experiment No. 44.) "I sat by the radiator while drinking. Almost immediately after the beginning of period 3, felt strong subjective effects, but was able to perform all the tests fairly well, I thought, until I stood up after the eye-movement test to take the station test. With the change of position from sitting to standing, there was a sudden desire to regurgitate. I endeavored to resist this, but it came so suddenly that I was unable to prevent an involuntary expulsion of about 100 c. c. of liquid. After spitting out this small amount, I immediately felt comfortable and was able to proceed without further interruption. At the end of period 4 it was not possible to urinate, and at the end of the next two periods it was only by the greatest effort that urine could be passed. The bladder and urinary tract seemed partially paralyzed and beyond the usual control. Fairly large quantities of urine did not appear until about 4 p.m. Urine was passed at 5^h25^m p.m. and I went home between 5^h30^m and 5^h55^m p.m. By this time the urine was exceedingly difficult to retain. I noticed marked flushing and warmth of the face beginning with the fourth period of the experiment, and think the skin temperature of the face must have been high. The subjective symptoms were the same as usual, though stronger to the point of numbness of the arms and legs. When I rubbed the back of the head with my hands there seemed to be considerable difference in the temperatures of the two surfaces. When my hands were rubbed together they felt strange, hardly like my own. My hands were especially clumsy and fumbled in turning the switches for the electric lights. There was also slight indirection in any attempt to touch specific parts of the face with my hands. About 15 minutes after the complete ingestion of the dose, and continuing for 15 or 20 minutes, there was a blurring of vision which pulsated in time with the heart-beat. There was no difficulty in the coordination of the two eyes, but the lids felt heavy. I was able to keep in time with the metronome in the eye-movement task, and thought I performed the pursuitmeter test fairly well. In the finger-movement test it was impossible to make the usual amplitudes, although the hands did not seem much colder than usual. In the station test, while my legs felt numb, I had the impression that I stood more quietly than normal, except for occasional sudden jerks of the body. My movements were more clumsy than usual, and in walking, I was unable to avoid running into the tables and chairs, which seemed to occupy more floor space than usual. At the sixteenth period I had not returned entirely to normal, but felt that I was approaching it. Enjoyed dinner at 6^h30^m p.m. and was comfortable during the evening."

Series G.—Standard dose preceded by 500 c. c. water taken 1 hour before. (Experiment No. 47.) "Alcohol effects disappeared earlier, about the end of the tenth period. Somewhat more prominent than usual in periods 3 and 4. Feeling of heaviness in arms was striking. Large amounts of urine at beginning, but difficult to pass urine in period 16." (Experiment No. 49.) "Some subjective effects, but not so strong as when no water taken before experiment."

Series H.—Standard dose, with 500 c. c. whole milk taken 1 hour before. (Experiment No. 48.) "Subjective effects not at all prominent." (Experiment No. 50.) "Vision and coordination not so confused as on several earlier occasions. Kept a good pace throughout. Think I made some of the best records in standing I have ever made."

Series I.—Standard dose, with 500 c. c. of water 1 hour afterward at beginning of period 7. (Experiment No. 45.) "After drinking the water the subjective effects, to my surprise, became less. About the end of period 13 I felt the influence of the alcohol was gone, but the sensations were again felt near the end of the fourteenth and beginning of the fifteenth periods." (Experiment No. 51.) "Did not feel in the best of condition to-day and found difficulty in passing urine, which surprised me, as 1,500 c. c. of liquid had been taken."

Series J.—Standard dose, followed by 500 c. c. whole milk taken 1 hour afterwards. (Experiment No. 46.) "Characteristic subjective effects seemed quite slight by the eleventh or twelfth periods." (Experiment No. 53.) "Subjective effects present in periods 3 to 9 inclusive."

Series K.—Standard dose, with muscular work on bicycle ergometer in periods 3, 5, 7, 9, 11, 13, and 15. (Experiment No. 64.) "Immediately after drinking and until work began, the subjective effects were as usual. On dismounting at the end of period 3, felt clumsy, but the feeling quickly disappeared. Experiment passed rapidly, with much reduced alcohol effect. Was surprised that the effect of the alcohol was so much less than usual." (Experiment No. 65.) "At end of period 3, felt the effect of alcohol in my knees, but not much afterwards. In the last three periods, think my standing records were as quiet as any I have ever made." (Experiment No. 66, control experiment with work.) "At the end of period 3, legs felt cramped, but not so unsteady as in alcohol experiment. Did not perspire so much during work as before, although temperature conditions were the same as in the alcohol experiments."

EXPERIMENTS WITH GROUP OF MEN WITH DILUTE ALCOHOL.

As in the earlier studies, the comments and subjective impressions of the men in the group given dilute alcohol were recorded. These were the results of no formal questioning, but were incidental and voluntary observations, many of them being contributed in friendly chats at the end of the experimental day.[a] As for the typewriting study, the notes are grouped chronologically for each subject.

Except on the second day with each man, the dose used was the standard dose for *Mow*, i. e., 27.5 grams of alcohol, diluted to a volume of 1,000 c. c., and taken at the end of the second period. On the second day, the 27.5 grams of alcohol were taken in a concentrated solution, with a volume of only 100 c. c.

Faf.

May 20, 1921. Alcohol. Several times spoke of "a slight whirling sensation about my head." "If I try, I can walk all right." "The difficulty is that I feel hazy, and when I turn quickly it seems that my brain turns a little later than my body." It being probably the first time that *Faf* had taken enough alcohol to produce these effects, they interested him considerably.

June 1, 1921. Alcohol, concentrated dose. Immediately after drinking he complained that the beverage burned his mouth and asked if he might rinse it with water. Although this was undesirable from the experimenter's point of view, it was permitted. The subject tried to spit out all the water taken into the mouth. About 20 minutes after drinking, he spoke of a "dazed feeling" and slight vertigo, "not more prominent than yesterday." A little later, "feel as though I had just wakened from sound sleep with the lack of ambition and drive that one experiences then." Thought the effects passed away a little more quickly on this day than previously. The subject was talkative, but there was a difficulty in his speech. He would sometimes move his lips considerably before any vocalization occurred.

June 28, 1921. Control. "Feel no effects; think you must have given me a blank."

June 29, 1921. Alcohol. Some 30 minutes after dose: "Feel slow; hard to bring things to pass; have to drive myself." Dr. Aub was present in period 5 during the knee-jerk and skin-temperature measurements. The author recalls this as the only time a visitor was present at any of the experiments reported in this volume. On the following day, *Faf* commented on his experience subsequent to this experiment. "On returning to the hospital, felt just a slight swaying, like being up in the top of a tree; had no headache."

June 30, 1921. Alcohol. 35 minutes after dose: "Less sure of myself than before in these experiments; the drink must have been stronger." During the pulse counts, 1½ hours after the alcohol, he was asleep. Subject had assisted in the hospital operating room continuously from 8^h30^m to 11^h00^m a.m. "There was lots of ether, but I was not sleepy when I came." He took the alcohol at 2^h05^m p.m.

July 1, 1921. Control. "Nothing in it; just drinking a lot of fluid."

Kom.

May 25, 1921. Alcohol. At end of experiment: "About 20 minutes after drinking felt slight dizziness, but after that the sensations seemed to disappear."

May 27, 1921. Alcohol, concentrated dose. "The experience is just the same as before, or possibly a bit stronger; just a little dizzy, sleepy feeling."

June 2, 1921. Alcohol. 'The strongest influence came to-day in the fourth period, a sleepy, drowsy feeling; slightly dizzy."

June 3, 1921. Alcohol. "Felt effects of drink to-day same as yesterday; no nausea or headache; slight belching." "Yesterday and to-day noticed less steadiness in standing after alcohol, and had difficulty in concentrating on the pursuitmeter task."

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[a] These subjective impressions have not been made use of in Chapter VI, but they may be compared with the recorded data for these experiments, if desired, by reference to tables 54 to 69 and figures 37 to 50.

Kac.

May 31, 1921. Alcohol. At 35 minutes after drinking: "I am a little dizzy, but could go down town without any difficulty. I can do anything I wish, but I have to watch myself very closely." "At other times have had a stronger alcohol influence, so it is not novelty that makes me notice it."

Hic.

June 6, 1921. Alcohol. Before beginning the experiment he expressed belief that 1 liter of fluid would slightly nauseate him. On being questioned later, said: "One or two times after drinking I felt a little uneasiness in the stomach." Nothing else of a subjective nature was noted by the subject. This is significant in consideration of the low concentration of alcohol appearing in blood and urine samples for this day. (See tables 54 and 55, pages 212 and 213.)

June 8, 1921. Alcohol, concentrated dose. About 10 minutes after taking the beverage: "Feel dizzy when I move, that is, when I stand up, but can control it by will power. It is noticeable when I am standing up doing nothing."

June 10, 1921. Alcohol. "Noticed alcohol influence, just dizziness; not so strong as on second day. Also my face is not so hot to-day as before."

June 11, 1921. Alcohol. "Only slight effects, less even than yesterday. My stomach is in good condition."

June 13, 1921. Control. "No sensation. My experience contrasts quite clearly with that of yesterday and the day before."

Jem.

June 13, 1921. Alcohol. Ten minutes after drinking reported slight nausea. Following first blood sample had tendency to regurgitate, which was successfully inhibited. On going to the adjoining room for the urine sample 20 minutes after ingestion: "Noticed unsteadiness and dizziness. This persisted and was clearest when I got up from sitting." "I noticed some difficulty in working; on finishing one line of the code, I seemed to be slow in starting the next, but the thought occurred to me that I was as accurate as ever."

June 14, 1921. Alcohol, concentrated dose. "No nausea and not disagreeable. Some dizziness and peculiar confidence in myself were experienced. A mistake does not worry me; nothing of that sort seems to matter. Others seem to be talking at a distance from me." On going from the pendulum test for the first blood sample, was noticeably unsteady. On day following this experiment he said: "Last night after supper I seemed to be unusually fatigued."

June 15, 1921. Control. "Did not feel any very dizzy effects, not even when jumping up and starting for some other part of the room."

June 16, 1921. Alcohol. "There was some dizzy feeling which I could not shake off." "It was hard for me to talk, there was a thickness of speech, and I was forgetful." The subject did not cooperate in the adjustments for the tests as he had on the previous day.

June 17, 1921. Alcohol. "Some dizziness was experienced for about 1½ hours, but the effect was milder than yesterday and I returned to normal more quickly." His food was the same as on the preceding day, except that the previous meal on this day included a glass of milk.

June 18, 1921. Control. "Think there must have been no alcohol; at least the effects were not present; no nausea, no dizziness."

Sul.

June 16, 1921. Alcohol. "There were typical alcohol sensations soon after taking the alcohol. I could notice dizziness when standing but not when sitting. In the standing test I could feel myself moving around more, and I made a mistake in the code test." *Sul* was surprised during the experiment that more than one blood sample was desired. He was somewhat confused mentally and showed instability when walking.

June 20, 1921. Alcohol, concentrated dose. "Within 3 or 4 minutes noticed a swimming feeling in the head and a little numbness of hands and fingers. The knees were weak, but there was nothing unpleasant about it. I wanted to sing." Both experimenter and assistant noted the exuberance and otherwise strong effect on this occasion. During a short intermission, *Sul* sat down in an office chair which, as usual, has a tilting back held in place by a stiff spring below the seat. On leaning back naturally in the chair it, of course, tilted; this gave the subject a fright for he thought the tilting due to his condition.

June 27, 1921. Control. "Felt a little sleepy and tired, but by the end of period 3 it was all gone."

June 29, 1921. Alcohol. "The drink made me slightly unsteady, but was noticed mostly in producing a little drowsy feeling." No exhilaration noted, as with the concentrated dose.

June 30, 1921. Alcohol. "Same effect as yesterday." During the knee-jerk test in period 3 there was labored breathing.

July 1, 1921. Control. "Felt nothing unusual; think there was little or no alcohol in the dose." *Sul* was cold 30 minutes after drinking and put on his coat.

Rir.

July 5, 1921. Alcohol. On the day previous he had taken an abnormal amount of strenuous exercise in the sun and very heavy food. "Noticed a little nausea at the time of the second blood sample (40 minutes after dose), but only for 3 or 4 minutes. Hardly any sensations that I could notice, so that the effects were much less than I have had at other times."

July 6, 1921. Alcohol, concentrated dose. "Felt a stimulation or exhilaration for about 20 minutes and later a sleepy condition. No vertigo present." To those observing him, *Rir* gave no certain indication of an alcohol effect.

July 7, 1921. Control. "No effects, not even slight."

July 8, 1921. Alcohol. "Little nausea in periods 3 and 4; no headache, but thick-headed and faint dizziness."

July 11, 1921. Alcohol. "No nausea, no dizziness, but sleepy in periods 4 and 5. Little headache due to microscopic work this morning. The effect was even less than the time before. Feeling quite normal at start and finish."

July 14, 1921. Control. "Less alcohol influence than any previous day; have not been annoyed by the warm weather; did not perspire so much to-day."

July 19, 1921. Alcohol. "Did not notice anything new or different. Could notice the alcohol in period 4; slight headache, but no other symptoms."

Cef.

Cef was an habitual user of alcoholic beverages of long experience. He was 52 years old. Began drinking at 17 years of age, "regularly 1 to 10 glasses per day." Had "sworn off" for 6 to 8 months at different times, but during the previous 2½ years had been drinking a good deal. His recent work had involved the caring for many cages of small laboratory animals.

July 13, 1921. Alcohol. "What I drank to-day tasted well; volume not large if you are thirsty; would hardly know it contained alcohol.

July 15, 1921. Alcohol, concentrated dose. "Could feel the dose inside of 2 minutes; another drink the same size would have started me talking to myself. The strongest feelings were 15 or 20 minutes after it was taken. Did not get any worse, but they gradually grew less. No unsteady feeling in legs or dizziness. You can feel a heat all over your body resulting from it. It made no difference in my work here; it helped me out in sitting quiet and stuff of that kind; could stand steadier with it than without it."

It was very unfortunate that this man broke an ankle a day or so later and was unable to continue the experiments.

Sut.

September 27, 1921. Alcohol. This man is an occasional immoderate drinker. Following the experiment he said: "The beverage was not hard to take. I noticed a faint effect, not enough to disturb coordination. There was a little dryness of the mouth and throat, which I usually experience after taking alcohol."

September 30, 1921. Alcohol, concentrated dose. Reported that no effects were experienced. The protocols show that *Sut* took 300 c. c. of water 1 hour before the dose and that his lunch, consisting of a cheese sandwich and one cup of coffee, was taken 2 hours before the alcohol.

October 10, 1921. Control. "The drink seemed to taste entirely different to-day; no after-taste, as usually comes following alcohol." "It made me a little cold to drink the 1 liter of beverage."

October 14, 1921. Alcohol. "Found no effects except from the mucous membrane of the mouth."

October 18, 1921. Alcohol. No comments indicating any subjective experience characteristic of alcohol ingestion.

October 21, 1921. Control. "Think I am starting a cold; slight headache and congested condition."

A perusal of these comments, scattered and fragmentary as they are, shows that for a majority of the subjects 27.5 grams of ethyl alcohol in a liter of diluted grape juice produced noticeable subjective symptoms. This volume of liquid, except in one or two instances, was not thought too large. The men as a rule could easily tell which days were "alcohol." The effects were commonly reported as most prominent within the first 35 to 40 minutes following the complete ingestion, and were most noticeable when the subjects rose, stood, or walked. There were individual differences in sensitivity to the alcohol and for intensity of the effect. Only the seasoned habitual drinker, *Cef*, was confident that he performed some of his laboratory work better after alcohol.

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